APPENDIX A

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APPENDIX A

WORK PROCESS SCHEDULE
MECHATRONICS TECHNICIAN
O*NET-SOC CODE: 49-2094.00 RAPIDS CODE: 2014CB

This Appendix is attached to and a part of these Standards for the Mechatronics Technician Apprenticeship Program.

1. TERM OF APPRENTICESHIP

If these Standards of Apprenticeship are being implemented as a competency-based approach, the occupation is not constrained by time. The term of apprenticeship will provide sufficient on-the-job learning and related instruction to enable the apprentice to attain the required competencies and PMMI Certificates as stated in the following Work Process Schedule and Related Instruction Outline. To complete the apprenticeship program, the apprentice must satisfactorily fulfill all on-the-job learning and related instruction requirements, attain the required competencies, and meet all required PMMI Certificates Criteria. Full credit will be given for the probationary period.

Attaining a PMMI Certificate will require approximately ninety (90) hours of related instruction through a Mechatronics Engineering Technology Associate Degree Program, vendor specific courses aligned with required competencies, or through a coalition of companies that form an industry partnership dedicated to delivering world-class educational opportunities to apprentices preparing for careers as Mechatronics Technicians. In the most technically advanced companies, training for this occupation may require all twelve (12) PMMI Core Certificates, an investment of approximately 1080 hours of related instruction.

To complete the apprenticeship program, the apprentice must satisfactorily fulfill both the on-the-job-learning and related instruction requirements, attain the required competencies and meet all required PMMI Certificate Criteria. The term of apprenticeship must provide on-the-job learning and related instruction that will enable the apprentice to attain the required PMMI Certificates. The sponsor will determine the PMMI Certificates that demonstrate a level of competency and proficiency equivalent to a journeyworker level Mechatronics Technician at the sponsor's company. A minimum of 576 hours of related instruction will be required to complete a Mechatronics Technician competency-based apprenticeship program.

2. RATIO OF APPRENTICES TO JOURNEYWORKERS

To ensure adequate supervision and training, it shall be the policy of the Program Sponsor to employ not more than one (1) apprentice for every one (1) journeyworker.

3. APPRENTICE SALARY SCHEDULE

Apprentices shall be paid a progressively increasing salary based on the apprentice's performance and position in the Salary Range. The entry-level salary of an apprentice will be determined based on the apprentice's previous experience and education; therefore, the starting salary may vary from one apprentice to another.

APPRENTICE SALARY SCHEDULE
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Apprentices receive an annual performance review which determines any potential salary increase. During the four (4) years of apprenticeship, the apprentice's performance is reviewed and the apprentice is considered for a salary increase every six (6) months or 1000 hours of on-the-job-learning. The apprentice will receive his/her first salary increase when a satisfactory performance review is achieved.

The entry-level salary for each apprentice will be determined based on the apprentice's previous experience and education; therefore, the starting salary may vary from one apprentice to another. The median US Hourly Rate for a Mechatronics Technician Journeyworker as of February 14, 2014, was $25.31

	TIME FRAME	WAGE RATE	PERCENT OF JOURNEYPERSONS HOURLY RATE
1.	0 to 6 Months	$15.00	59 % of Journeyworkers Hourly Rate
2.	7 to 12 Months	$16.50	65 % of Journeyworkers Hourly Rate
3.	13 to 18 Months	$18.00	71 % of Journeyworkers Hourly Rate
4.	19 to 24 Months	$19.50	77 % of Journeyworkers Hourly Rate
5.	25 to 30 Months	$21.00	83 % of Journeyworkers Hourly Rate
6.	31 to 36 Months	$22.50	89 % of Journeyworkers Hourly Rate
7.	37 to 42 Months	$23.50	93 % of Journeyworkers Hourly Rate
8.	43 to 48 Months	$24.50	97 % of Journeyworkers Hourly Rate

4. SCHEDULE OF ON-THE-JOB LEARNING AND RELATED INSTRUCTION

MECHATRONICS TECHNICIAN OCCUPATION DESCRIPTION

Highly-skilled Mechatronics Technicians work with complex high-performance manufacturing systems and are able to analyze, troubleshoot and repair systems to maintain process efficiency. They must understand and analyze the technical specifications of mechatronic systems, subsystems, modules and components; perform scheduled and preventive maintenance to detect and prevent problems; use troubleshooting skills to identify and prevent possible problems and failures, and to systematically and intelligently make repairs; incorporate relevant technical literature into the understanding of system operation and coordinate efforts with other technicians involved in installing or maintaining equipment or components; install, repair, adjust, and test equipment and components to ensure that systems function properly; communicate with machine operators, and operate equipment to detect equipment problems, analyze malfunctions, and verify system problems; and observe and incorporate safety standards and regulations required for safe operation of the system.

COMPETENCY REQUIREMENTS

The following outlines the *competency requirements* for the Mechatronics Technician occupation, including the approximate hours of structured *on-the-job learning* and the approximate hours of *related instruction* which *supplements* the structured on-the-job learning. To complete the apprenticeship program, the apprentice must satisfactorily fulfill both the on-the-job learning and related instruction requirements, attain the required *competencies* as defined in the following outline, and meet all required *PMMI Certificate Criteria*.

This is a competency-based training approach and is not constrained by time. The term of apprenticeship will provide sufficient on-the-job learning to enable the apprentice to attain the required competencies. The sponsor will determine when the apprentice satisfactorily completes program requirements and will request a *Certificate of Completion of Apprenticeship* when the apprentice demonstrates a level of competency and proficiency equivalent to a journeyworker level Mechatronics Technician.

MECHATRONICS TECHNICIAN CAREER LATTICE

Individuals who become Mechatronics Technician Apprentices will, for the most part, come from two directions.

Often, they are incumbent workers who have a considerable amount of on-the-job experience. They may have begun their career with a company as a material

handler or laborer and moved into a machine operation role. These folks have a good deal of tacit understanding of the manufacturing processes. Other potential apprentices are coming out of an educational situation where they have lots of knowledge, but very little practical experience.

PMMI recognizes these different pathways and has defined competencies for people in both situations that it considers helpful in preparing to become an apprentice. Most often, these competencies can be offered in two courses: Manufacturing Fundamentals and Introduction to Shop Machinery.

Manufacturing Fundamentals is an overview of manufacturing including a description of the types of manufacturing, the place of manufacturing in a regional economy, the role of automation in productivity, a definition of mechatronics in manufacturing, and an introduction to blueprints and measuring. Introduction to Shop Machinery provides hands-on training on the use of certain hand and power tools including bench vice, hacksaw, file, threading tool, stamping punch, band saws, drill press, milling machines, and lathes.

It is recommended that potential apprentices find a way to acquire the skills at this level before they apply to become an apprentice since they are fundamental to the programming that happens in the Apprenticeship Program itself. This can be done through on-the-job learning or through classes that are offered through training providers in the region.

Selection into the Mechatronics Technician occupation Apprenticeship Program will be in accordance with the Selection Procedures in Appendix D. Apprenticeship candidates that combine education and experience to achieve a high level of performance will have the opportunity to progress through the Mechatronics Technician Career Lattice, detailed in the following graphic:

MECHATRONICS TECHNICIAN CAREER LATTICE

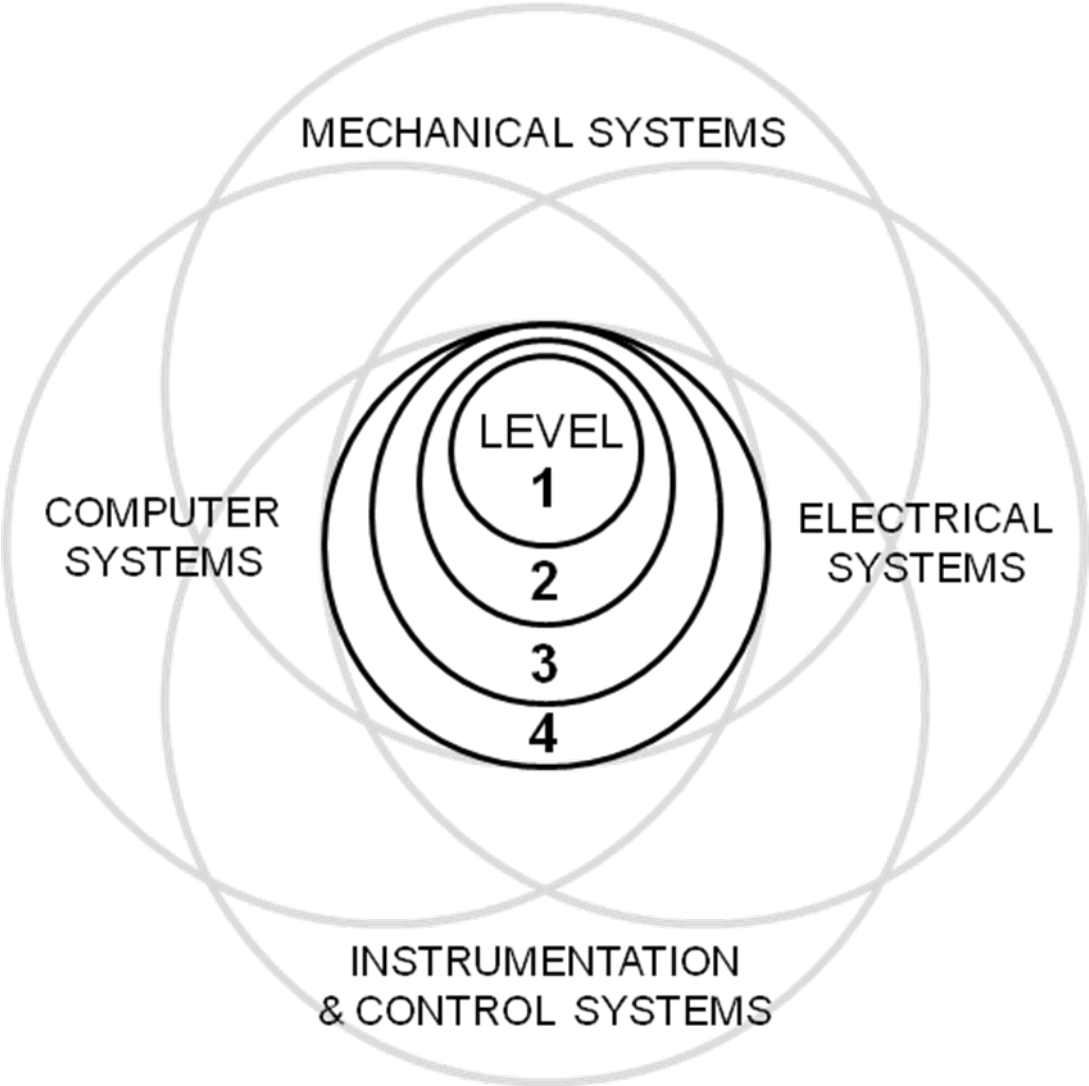
- Entry-Level Employees
- Certified Machine Operators
- Qualified Apprenticeship Candidates
- Mechatronics Technician Apprentices
    - PMMI Core Certificates
        - Mechanical Components I and II
        - Industrial Electricity I and II
        - Programmable Logic Controllers I and II
        - Fluid Power I and II
        - Motors and Motor Control
        - Robotics and Motion Control
    - Machining Certifications (optional)
    - Welding Certifications (optional)
- Competent and Proficient Mechatronics Technicians
- Mechatronics Engineering Technology Degrees

As the apprentice progresses through the Mechatronics Technician Career Lattice, the sequence of attaining PMMI Certificates does not have to follow a specific sequential order. For example, “First Level Apprentices” will often gain more experience working with Mechanical Systems and may complete all Mechanical Systems PMMI Certificates before completing the third Level of the apprenticeship program.

Apprentices first meet related instruction and on the job learning requirements, and then utilize the competency check lists to confirm readiness for a PMMI Certificate Exam. It is important to remember that the Mechatronics Technician occupation includes skills and competencies aligned with Mechanical Systems, Electrical Systems, Computer Systems, and Instrumentation and Control Systems. The apprentice will master select skills and competencies from each of these disciplines. For example, the Mechatronics Technician will master only a fraction of the skill set of a Maintenance Electrician that focuses strictly on Electrical Systems.

As apprentices progress through the apprenticeship program the sequence of learning may vary from apprentice to apprentice. The attainment of PMMI Certificates may also

vary from apprentice to apprentice. The goal is for all Mechatronics Technician Apprenticeship Programs to be aligned with an Engineering Technology Associate Degree that articulates to a Four-Year Mechatronics Engineering Technology Degree.



MECHATRONICS TECHNICIAN WORK PROCESSES

At a very basic level, the Mechatronics Technician Apprenticeship Program focuses on the transfer of skills and knowledge from one or more subject matter experts to an apprentice. The subject matter experts are called journeyworkers, persons who are recognized within the industry as having expertise in this specific occupation. In a manufacturing environment that is transitioning from a conventional to a multi-skilled workforce, there may not be journeyworkers in the multi-skilled Mechatronics Technician occupation. Existing journeyworkers may be in conventional, single craft occupations. In this case, these journeyworkers may be substituted for journeyworkers in the multi-skilled Mechatronics Technician occupation.

In practice, the journeyworker mentors the apprentice, ensuring that the skills and knowledge attained by the apprentice lead to a proficiency level that enables the apprentice to competently perform the occupation to the industry standard. The occupational requirements are always defined by the partnering company.

Skills are learned through a structured, systematic program of on-the-job supervised learning, supplemented by related instruction that provides the theoretical knowledge associated with the apprenticeable occupation.

The schedule of work processes is a list of on-the-job-learning and work activities that the apprentice will experience during the apprenticeship program.

Work processes may be written as tasks, skills or competencies that lead to a proficiency level that enables the apprentice to competently perform the occupation to an industry standard. The Work Process Schedule also lists the approximate amount of time to be spent in each work process, providing sufficient time for an apprentice to learn and practice the various skills.

Practice provides for repetition of the skill, allowing the apprentice to master the skill and “own” it for life. Repetition provides an opportunity for an apprentice to experience variables that are common when performing a skill. Repetition also provides the opportunity to learn from a variety of subject matter experts or apprenticeship instructors that may demonstrate a variety of approaches to performing a skill.

What is important to remember is how apprentices learn. Apprentices learn by doing, practicing each skill until mastery. Courses that provide just the theoretical aspects of an occupation provide only the background for learning. Apprenticeship is really learning by doing. It is tacit rather than didactic.

Therefore, an important aspect of apprenticeship is to align the theory with on-the-job learning. The PMMI Core Certificates provide a series of assessments that verify the skills and knowledge achieved through on-the-job learning, related technical instruction assignments, and the Mechatronics Technician job requirements.

Work Processes tailored to the Partnering Company's Job Requirements

Overall, the work processes outlined below reflect the skills and knowledge that have been identified by manufacturers as basic to the broad-based manufacturing tasks that are part of a cluster of occupations on a career pathway that leads to a Mechatronics Technician. This career pathway often begins as a material handler, machine operator, or an occupation related to a single skill, such as a welder, mechanic, or electrician.

As identified in the USDOL Mechatronics Competency Model that underlies the skill standards that PMMI used to develop its Certificates, competencies related to mechatronics are at the end of a pathway that includes:

- ☐ Basic skills related to industry, in general, such as safety and manufacturing processes;
- ☐ More specific manufacturing skills such as use of hand tools, print reading, an understanding of lean manufacturing, and measurement;
- ☐ Skills associated with material handling, machine operation, and single crafts;
- ☐ The ability to apply knowledge in mechanical, electrical, computer and control technology to industrial maintenance tasks; and
- ☐ Finally, bringing all of the knowledge and skill together in an integrated multi-skilled, expert troubleshooter which is a Mechatronics Technician.

As employers engage apprentices, whether incumbents or new hires, they must be aware of the varied background that each individual brings to the program, and be able to provide wide-ranging on-the-job learning that allows an apprentice to bring the content from the classroom into the reality of the work situation. This will certainly involve the flexibility to allow the apprentice to move into on-the-job learning situations that recognize the individual's need to contextualize their didactic learning.

It will also necessitate the employer to provide mentors as appropriate and when needed from among the technical workforce. One would expect on-the-job learning to be cumulative and that the apprentice would become increasingly more productive to the employer as the apprentice's skills increase throughout the process.

PMMI Certificates primarily test didactic knowledge. On-the-job learning in context will certainly help the apprentice solidify this knowledge through real-world practice as an apprentice works through each unit of the work processes. In addition, PMMI is currently working on hands-on assessments that will complement the didactic assessments described above.

Testing for these units will be available through the educational units that offer training. The focus of the testing will be the learner actually demonstrating their skill with an assessment that focuses on troubleshooting and remediating faults in systems relevant to specific subject areas.

Employers that participate in this apprenticeship affirm that they can provide the on-the-job learning that addresses the industrial maintenance and mechatronics skills that are a part of the overall pathway and the skills that need to be acquired as part of it.

Regardless of the product being made, nearly every manufacturer will, at some level, have occupations that need the competencies described below. Employers take the responsibility when they make their commitment to hire the apprentice to provide the on-the-job learning in some way for the apprentice.

WORK PROCESS SCHEDULE
MECHATRONICS TECHNICIAN
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	STRUCTURED ON-THE-JOB LEARNING	Level
1.0	**Work Processes**	
1.1	Product quality and safety	1
1.1A	Dress and grooming requirements	
1.1B	Workplace and equipment sanitation requirements	
1.1C	Allergen and contamination protection	
1.1D	Hazard Analysis and Critical Control Points	
1.2	Workplace safety (General)	1
1.2A	Proper use of safety clothing and equipment	
1.2A1	Proper use of Personal Protective Equipment (PPE) and Arc Flash Techniques	
1.2B	Response to fire and other emergency situations	
1.2C	Safe Use and Care of Hand Tools	
1.2D	Proper lifting, material handling, fall protection and ladder usage techniques	
1.2D1	Fork truck or other license requirements	
1.2E	Confined space safety	
1.2F	Welding safety	
1.2G	Lockout - tagout procedures	
1.2H	Recognition of classified dust or gas explosion areas or other dangerous materials in the environment	
1.2J	Obtaining permits for welding, entry to confined spaces, etc.	
1.2K	Proper understanding and use of Material Safety Data Sheets (MSDS)	
1.2K1	Select and use correct Personal Protective Equipment (PPE)	
1.2K2	Take appropriate steps to respond to a spill	
1.3	Reserved	

	STRUCTURED ON-THE-JOB LEARNING	Level
1.4	Workplace security	1
1.4A	Access requirements for employees	
1.4B	Access requirements for contractors and outside service representatives	
1.4C	Secure handling of company documents	
1.4D	Data and network security requirements	
1.5	Locating and maintaining information	1/2
1.5A	Process Specifications and Standard Operating Procedures	
1.5B	Technical drawings	
1.5C	Vendor manuals and documents	
1.5D	Software and documentation	
1.5E	Operating manuals	
1.5F	Maintaining as-built and other revisions to documents	
1.6	Work order processes	1
1.6A	Operation and use of the company work order system	
1.7	Material control processes	1
1.7A	Operation and use of systems for maintaining parts inventories	
1.7B	Operation and use of systems for procuring parts	
1.7C	Processes for relocating or disposing of equipment	
1.8	Preventative Maintenance Systems	2
1.8A	Operation and use of systems for scheduling lubrication, calibration, predictive or preventative maintenance activities.	
2.0	Working and communicating with others	
2.1	Demonstrate ability to reliably follow the instructions of others	1
2.2	Demonstrate a willingness to ask questions about things not fully understood	1
2.3	Demonstrate the ability to work with due regard to the safety of others	1
2.4	Notebooks, logs and communications	1
2.4A	Establish a system of maintaining appropriate notes and reminders	
2.4B	Complete any required logs, calibration records, etc.	

	STRUCTURED ON-THE-JOB LEARNING	Level
2.5	Ensure proper communications between previous and next shifts, with operations and with supervision	1
2.6	Demonstrate the ability to solve problems within a group	2
2.7	Demonstrate the ability to identify problems and changes which could lead to problems through the exchange of information with operators, supervisors and others	2/3
2.8	Demonstrate the ability to establish trust and rapport with operators, supervisors and others	3/4
2.9	Demonstrate ability to effectively train others (Optional for field service)	4
	PMMI Certified Trainer Credential (Optional)	
3.0	Use of technical documentation (all documents may be paper or digital)	1
3.1	Demonstrate understanding of mechanical drawings	
	Use floor plans and equipment layouts	1
	Understand scale	1
	Understand tolerance	1
	Use and convert English and metric units of measure	2
	Be able to follow and verify a print against a layout or provide measurements to complete a layout	2
	Use plan, orthographic, isometric and exploded views of mechanical parts	2
	Be able to verify measurements of a part using scales, calipers, micrometers and other manual measuring devices	2
	Be able to interpret displacement, velocity, and acceleration graphs	3
	Be able to interpret instrument piping diagrams	3
3.2	Demonstrate understanding of fluid power drawings	
	Understand US and European symbols for pneumatic, vacuum and hydraulic systems	1
	Be able to follow and verify a print against a system	1
	Be able to sketch a pneumatic and hydraulic print from a system	2
	Be able to describe the sequence of operation by following the print	3

	STRUCTURED ON-THE-JOB LEARNING	Level
3.3	Demonstrate understanding of electrical drawings	
	Understand US and European symbols for electrical power and control systems	1
	Identify devices and conductors across multiple pages of a drawing using cross referencing for print navigation	1
	Use conduit and panel layout drawings to locate devices and conductors	1
	Be able to follow and verify a print against a system	2
	Be able to sketch a print from a system	
	Demonstrate proper procedures for identifying components and wiring in a system and on a drawing	1
	Be able to describe the sequence of operation by following the print	3
3.4	Demonstrate understanding of a Process and Instrumentation Diagram (P&ID) and process control loop drawings	
	Recognize P&ID and the equipment symbols used	2
	Utilize a P&ID for locating information and troubleshooting	3
3.5	Vendor documentation	2
	Demonstrate the willingness and ability to read and understand a user manual	
	Demonstrate the ability to use a troubleshooting flow chart	
	Demonstrate the ability to use bills of material and drawings to identify part numbers	
3.6	Software documentation	
	Demonstrate the ability to follow basic logic flow through a Programmable Logic Controllers (PLC) ladder logic program	1
	Demonstrate the ability to interpret a complex ladder diagram with advanced PLC functions including math, data moves, branches and subroutines	2
	Demonstrate the ability to identify memory/register functions that are used for transferring information across a network	3
	Demonstrate the ability to use appropriate languages of the IEC61131 programming standard	4
	Demonstrate the ability to utilize function blocks for process control	3/4
	Demonstrate the ability to utilize function blocks for motion control	3/4
	Demonstrate the ability to utilize robot program documentation	3/4

	STRUCTURED ON-THE-JOB LEARNING	LEVEL
4.0	Tools and Workmanship	
4.1	Use basic mechanics tools and measuring equipment (such as wrenches, drill motor, grinder, calipers, scale)	1
4.2	Use basic electrical tools and measuring equipment (such as wire stripper, fuse puller, Wiggins, Volt Ohm Meter (VOM), clampon)	1
4.3	Use specialized mechanical tools and measuring equipment (such as threading machine, crimper, vibration meter)	1/2
4.4	Use specialized electrical tools and measuring equipment (such as megger, network analyzer)	2
4.5	Use machine tools for basic functions (such as drilling, turning a shaft, creating a flat surface)	
4.6	Use calibration instruments for temperature, pressure, mass and appropriate process variables	3
4.7	Demonstrate quality workmanship for mechanical, fluid power, electrical, and instrumentation repairs, replacements or additions	
4.8	Perform all work in accordance for requirements for sanitation, safety, or other special needs	
4.9	Be able to select and properly use special tools necessary for special occupancies such as gas or dust ignition or chemical wash down areas	
5.0	Computer use	
5.1	Be able to use a personal computer (PC) with appropriate windows or linux operating systems	1
5.2	Use basic computer office tools such as word processing, spreadsheet, and database	1
5.3	Be able to use a browser and access the internet to retrieve information	1
5.4	Be able to install applications to a personal computer (PC)	2
5.5	Be able to configure wired and wireless networking for a PC	2
5.6	Be able to set up and configure a PC, monitor, printer, keyboard, and mouse	2
5.7	Be able to install or replace plug-in components, cards, memory, media in a PC or laptop	2
5.8	Be able to use a tablet device	2
5.9	Be able to add user accounts to a PC	1
5.10	Be able to install and use anti-virus software	1
5.11	Be able to follow a corporate security policy	1

	STRUCTURED ON-THE-JOB LEARNING	LEVEL
6.0	General machine installation and set-up	1
	Can locate a machine according to a print (non-critical machines +/- 1/8" or add Optional Rigging Certifications if necessary)	
	Can level a machine (non-critical machines +/- 1/8")	
	Can verify circuit size and protection	
	Can verify proper voltage and phasing	
	Can verify proper grounding	
	Can verify proper guards are in place	
	Can install proper mounts and raceways for adding a component (such as a sensor) or interlocking a machine	
	Can properly size, install, mark and test circuit conductors for adding a component or interlocking a machine	
	Can properly layout, cut, drill, tap and assemble a control station for an addition to a machine	
	Can connect compressed air to a machine from a supply header	
	Can verify proper air pressures and volumes for a machine	
	Can add pneumatic or hydraulic components and lines to a machine.	
	Can align and adjust shafts, motors, belts, and chains on a machine.	
	Can verify proper operation of all safety devices and circuits on a machine	
	Can ring out circuits on a machine	
	Can check and lubricate a machine	
	Can safely power up a machine	
	Can verify proper current draw of a machine	
	Can verify machine operation according to a sequence of operation	
	(Welding is not included. Add optional welding certifications if necessary)	

	STRUCTURED ON-THE-JOB LEARNING	LEVEL
7.0	Conveyors	1
	Can assemble rollers and belts	
	Can adjust height and distance to adjoining belts	
	Can adjust guides and rollers	
	Can reverse direction of travel	
	Can set and adjust tracking	
	Can measure and adjust belt speed	
	Can determine if proper guards are in place	
	Can adjust and modify guards and verify safe operation	
8.0	Other common machines appropriate to the operation	1
	Setup, test, operate, load materials, etc as appropriate	
9.0	Troubleshooting, maintenance and repair of components - Demonstrate ability to understand, identify, locate malfunctions, remove, replace, adjust and return to service the following types of industrial components	
9.1	Mechanical components	
	Bearings in a bore or on a shaft	1
	Bushings	1
	V-belts (light and heavy duty) and timing belts	1
	Roller chains (light and heavy duty)	1
	Sheaves	1
	Sprockets	1
	Shafts, keys and hubs	1
	Couplings	1
	Clutches and brakes	2
	Gears and gear assemblies (spur, bevel, worm, helical, parallel right angle)	2
	Gaskets	2
	Seals	2
	Linear bearings	2
	Ball screws	2

	STRUCTURED ON-THE-JOB LEARNING	LEVEL
9.2	Industrial Electrical components	2/3
	Lighting fixtures, switches, dimmers, etc.	
	Industrial pilot devices (lamps, buttons, switches, horns)	
	Protective devices (disconnects, fuses, breakers, overloads)	
	Motor control devices (starters, auxiliary contacts, capacitors, resistors)	
	Motors	
	Single phase alternating current (AC)	
	Three phase AC (up to 600 volts)	
	(Direct Current) DC	
	Transformers	
	Heaters	
	Clutches and brakes	
	Solenoids	
	Directional control valves	
	Limit, pressure and vacuum switches	
9.3	Industrial electronic sensors and components	3/4
	Photoelectric sensors of various types	
	Proximity sensors of various types (inductive, capacitive, ultrasonic)	
	DC power supplies	
	Electronic motor drives	
	Silicon Controlled Rectifier (SCR) drives	
	Variable frequency drives	
	DC drives	
9.4	Electrical control components	2/3
	Relays	
	Timers	
	Counters	

	STRUCTURED ON-THE-JOB TRAINING	LEVEL
9.5	Pneumatic Components	2/3
	Regulators	
	Filters	
	Lubricators	
	Dryers	
	Check valves	
	Flow control valves	
	Relief valves	
	Dump valves	
	Manual switches and operators	
	Directional control valves, (3/2, 4/2, 4/3, 5/3, manual, single coil, multiple coil)	
	Cylinders	
	Motors	
9.6	Hydraulic Components	2/3
	Pumps	
	Regulators	
	Filters	
	Check valves	
	Flow control valves	
	Relief valves	
	Manual switches and operators	
	Directional control valves (3/2, 4/2, 5/2, manual, single coil, multiple coil)	
	Cylinders	
	Motors	

	STRUCTURED ON-THE-JOB LEARNING	LEVEL	APPROX HOURS
9.7	Vacuum system components	2/3	
	Pumps		
	Generators		
	Switches		
	Cups		
10	Troubleshooting, maintenance and repair of systems and components Demonstrate the ability to understand, identify, locate malfunctions, remove, replace, adjust and return to service all manner of systems comprised of the various combinations of the components identified in Section 9 and the Level 1 items of Section 11. These mechanical, fluid power, electrical, electro-mechanical and electro-fluid power systems shall be identified by the employer for the particular environment.	2	
11	Programmable Logic Controllers (PLC's) and Programmable Automation Controller (PAC's)		
	Install basic components of a PLC including racks, power supply, processor, and single point digital input/output modules	1	
	Connect power and digital input/output wiring to a PLC	1	
	AC I/O to 120 volts	1	
	DC I/O to 48 volts	1	
	Select and appropriately connect sinking and sourcing inputs and outputs	1	
	Identify failures of the PLC hardware by the use of indicator lights, remove and replace faulty components and return the system to operation	1	
	Configure and connect a laptop or other programming device to a PLC, upload, download and save a program	1	
	Change preset timer and counter values and apply and remove forces from a program	1	
	Troubleshoot field devices and wiring by observing PLC indicator lights and making other appropriate electrical measurements	1	
	Troubleshoot a machine or process by observing PLC indicator lights and reviewing the PLC software ladder diagram (relays, timers and counters)	1	

	STRUCTURED ON-THE-JOB LEARNING	LEVEL
11	Programmable Logic Controllers (PLC's) and (PAC's) **(CONTINUED)**	
	Add a function to a machine or process that requires wiring of additional I/O and basic ladder logic programming	2
	Troubleshoot a PLC or a PLC controlled machine or process by observing input and output conditions and monitoring the program in real time	2
	Install and configure advanced components in a PLC such as remote I/O, analog I/O, BCD or other multi-point digital I/O, communications cards, encoder cards, etc.	2
	Properly install and terminate wiring for low level analog signals	2
	Troubleshoot a machine or process utilizing remote I/O	2
	Troubleshoot a machine or process utilizing special I/O modules	2
	Troubleshoot a machine or process utilizing math, data move, and program control instructions	2
	Troubleshoot a machine or process utilizing a one to one PLC/Human Machine Interface (HMI) arrangement	2
	Troubleshoot a machine or process utilizing multiple PLC's on a network	2
	Troubleshoot a machine or process utilizing one to many, many to one and many to many configurations of PLC and HMI	2
	Troubleshoot PLC systems connected with single line, multi-line and PC-based HMI	2
	Troubleshoot the safety systems associated with a PLC, such as an external master control relay	2
	Troubleshoot a machine or process utilizing a PLC or a Programmable Automation Controller PAC that implements closed loop process control	3
	Troubleshoot a machine or process utilizing a PLC or a Programmable Automation Controller PAC that implements general purpose multi-axis motion control	3
12	Instrumentation and Process Control Components and Systems	3/4
12.1	Sensors	
	Temperature sensors	
	Flow sensors	
	Pressure sensors	
	Level sensors	
	Specialized sensors	

12.2	Signal processing	
	Transmitters	
	Analog electrical	
	Analog pressure	
	Digital	
	Conversion	
12.3	Final elements	
	Valves	
	Positioners	
	Heaters	
12.4	Proportional Integral Derivative (PID) Controllers	
	On/Off control	
	Time proportional control	
	Proportional control	
	Proportional - Integral control (PI)	
	Proportional - Derivative control (PD)	
	Proportional - Integral- Derivative control (PID)	
12.5	Single loop control	
	Construct	
	Configure	
	Calibrate	
	Tune	
	Operate loops - manual and automatic	
	Troubleshoot loops	
	Repair loops	
13	General Purpose Motion Control Systems (multiple coordinated axes)	3/4
13.1	Servo motors	
13.2	Feedback mechanisms	
13.3	Servo drives	

13.4	Motion controllers	
13.5	Motion networks	
13.6	Operations	
	Following operations	
	Gear operations	
	Cam operations	
	Line shaft operations	
	Clutching/braking operations	
	Torque control operations	
13.7	Implement	
	Configure	
	Tune	
	Operate	
13.8	Troubleshoot, remove, replace, return to service	
13.9	Troubleshoot specific systems and applications appropriate to the company's environment	
14	Robotic Systems	3/4
	Exercise appropriate safety procedures for working with robots	
	Identify the types of robots	
	Program robot movement with a teach pendant	
	Upload, download, save and run a robot program	
	Interface a robot to a conveyor system	
	Interface an end effector to a robot controller	
	Calibrate a robot to a conveyor system	
	Interface a robot to a vision system	
	Set up lighting for a vision system	
	Teach a vision system how to identify and orient good and bad product	
	Troubleshoot a robot system, replace components and return to operation	
	Perform repair procedures on a robot arm	

15.0	Lubrication	2
	Grease and oil specifications	
	Safety practices	
	Disposal and recycling	
	Automatic lubrication systems	
16.0	Preventive and Predictive Maintenance	4
	Apply vibration analysis	

MECHATRONICS TECHNICIAN RELATED INSTRUCTION OUTLINE

Harrisburg Area Community College (HACC)
Central Pennsylvania's Community College

HACC was established in 1964 and is the largest and oldest of Pennsylvania's fourteen (14) community colleges. The College serves students in the Central Pennsylvania region through campuses in Gettysburg, Harrisburg, Lancaster, Lebanon and York as well as off-site learning locations and a robust Virtual Campus.

Mechatronics Career Pathway

HACC offers a Mechatronics Diploma Program, Certificate Program and Associate Degree Program. The Diploma Program's requires twenty-five (25) credits are included in the Mechatronics Related Instruction Program.

The Mechatronics Related Instruction Program is designed to prepare apprentices to:

- Perform maintenance on electronic, electrical, pneumatic, hydraulic, industrial robots, and other mechanical equipment
- Interpret OSHA Standards
- Use hand tools, power tools, and test equipment
- Demonstrate practical knowledge in electrical and electronic fundamentals, motor controls, and process control systems
- Demonstrate practical knowledge in fluid systems
- Demonstrate practical knowledge in mechanical systems
- Read electrical and mechanical engineering drawings
- Troubleshoot and repair electromechanical equipment and systems
- Reference, interpret, and apply the National Electrical Code
- Program, wire, and troubleshoot basic PLC systems
- Effectively interact with and develop basic programs on industrial robots

RELATED INSTRUCTION OUTLINE
MECHATRONICS TECHNICIAN
O*NET- SOC CODE: 49-2094.00 RAPIDS CODE: 2014CB
HACC

Engineering and Technology Division

	COURSE CODE	COURSE TITLE	CREDITS
1.	GTEC 101	Safety in the Workplace	3
2.	MATH 161	Technical Mathematics for General Technicians	3
3.	ELOC 153	Fundamentals of Electricity	4
4.	IMT 108	Power Transmission	4
5.	IMT 110	Fluid Power	4
6.	ELEC 144	Electronics for Technicians	3
7.	IA 201	Motors and Controls	4
8.	IA 221	Sensor Technology	3
9.	IA 208	PLC's and Automation	2
10.	IA 213	Troubleshooting PLC's	3
11.	ELOC 172	National Electric Code (NEC)	2
12.	IA 210	Robotics I	3
13.	IMT 291	Industrial Maintenance Coop	3
14.	**- - - -**	**TOTAL RELATED INSTRUCTION CREDITS and HOURS**	**41**

The Mechatronics Related Instruction Program provides apprentices with the knowledge and skills necessary to advance in a manufacturing setting. Apprentices are prepared to maintain, troubleshoot, repair, and modify automated systems and equipment used throughout industry. Apprentices learn mechanical, electrical, electronic, fluid power, and control systems while gaining an understanding, through theory and hands-on experience, of how these systems integrate with one another.

MECHATRONICS ASSOCIATE DEGREE

Engineering and Technology Division

	COURSE CODE	COURSE TITLE	CREDITS
1.	IMT 108	Power Transmission	4
2.	GTEC 101	Safety in the Workplace	3
3.	ELOC 153	Fundamentals of Electricity	4
4.	MATH 161	Technical Mathematics for General Technicians	3
5.	ENGL 101	English Composition	3
6.	ELEC 144	Electronics for Technicians	3
7.	ENGL 104	Report and Technical Writing	3
8.	IA 201	Motors and Controls	4
9.	IA 221	Sensor Technology	3
10.	IA 208	PLC's and Automation	2
11.	IA 213	Troubleshooting PLC's	3
12.	ELOC 172	National Electric Code (NEC)	2
13.	COMM 203	Interpersonal Communication (COMM 101 Effective Speaking)	3
14.	IMT 110	Fluid Power	4
15.	IA 210	Robotics I	3
16.	IMT 291	Industrial Maintenance Coop	3
17.	- - - -	Program Technical Elective	3
18.	- - - -	Program Technical Elective	3
19.	- - - -	Core A Elective	3
20.	- - - -	Core B Elective	3
21.	- - - -	Core C Elective	3
22.	- - - -	Physical Education	1
23.	**- - - -**	**TOTAL ASSOCIATE DEGREE CREDITS and HOURS**	**66**

Revised: 11/15/2013

MECHATRONICS TECHNICIAN RELATED INSTRUCTION OUTLINE

READING AREA COMMUNITY COLLEGE (RACC)

Reading Area Community College (RACC) was founded on October 1, 1971, and is sponsored by the Berks County Board of Commissioners. In 1996, the college completed a campus expansion plan that included the new Schmidt Training and Technology Center that provides training in manufacturing technology, information technology, and workplace readiness.

Science and Mathematics Division
Mechatronics Engineering Technology Associate Degree Program

The Mechatronics Engineering Technology Program prepares apprentices for careers as technicians in advanced manufacturing settings. Apprentices gain knowledge and skills in print reading, CAD drawing, mechanics, pneumatics, hydraulics, electricity, motors, motor control, programmable logic controls, robotics and motion control, process control, instrumentation and computer integrated manufacturing. Emphasis is placed on predictive maintenance, troubleshooting and quality assurance.

RELATED INSTRUCTION OUTLINE
MECHATRONICS TECHNICIAN
O*NET- SOC CODE: 49-2094.00 RAPIDS CODE: 2014CB

RACC

READING AREA COMMUNITY COLLEGE

	COURSE CODE	COURSE TITLE	CREDITS
1.	MET 100	Introduction to Shop Machinery	1
2.	MET 110	Manufacturing Fundamentals	3
3.	MET 120	Industrial Mechanics I	3
4.	MET 130	Industrial Electrical Systems	4
5.	MET 140	Introduction to Programmable Logic Controllers – SLC500	4
6.	MET 150	Industrial Mechanics II	4
7.	MET 160	Rotating Electrical Machines	3
8.	MET 200	Robotics and Motion Control	4
9.	MET 210	Process Control and Instrumentation	3
10.	MET 220	Advanced PLCs (ControlLogix or S7)	4
11.	MET 230	Integrated Manufacturing Systems	3
12.	MET 240	Mechatronics Application Project	4
13.	**- - - -**	**TOTAL RELATED INSTRUCTION CREDITS and HOURS**	**40**

The Mechatronics Related Instruction Program prepares apprentices for careers as technicians in advanced manufacturing settings. Apprentices gain knowledge and skills in print reading, CAD drawing, mechanics, pneumatics, hydraulics, electricity, motors, motor control, programmable logic controls, robotics and motion control, process control, instrumentation and computer integrated manufacturing. Emphasis is placed on predictive maintenance, troubleshooting and quality assurance.

RACC

READING AREA COMMUNITY COLLEGE

Science and Mathematics Division

MECHATRONICS ENGINEERING TECHNOLOGY ASSOCIATE DEGREE PROGRAM

	COURSE CODE	COURSE TITLE	CREDITS
1.	MET 100	Introduction to Shop Machinery	1
2.	MET 110	Manufacturing Fundamentals	3
3.	MET 120	Industrial Mechanics I	3
4.	MET 130	Industrial Electrical Systems	4
5.	MET 140	Introduction to Programmable Logic Controllers – SLC500	4
6.	MET 150	Industrial Mechanics II	4
7.	MET 160	Rotating Electrical Machines	3
8.	MET 200	Robotics and Motion Control	4
9.	MET 210	Process Control and Instrumentation	3
10.	MET 220	Advanced PLCs (ControlLogix or S7)	4
11.	MET 230	Integrated Manufacturing Systems	3
12.	MET 240	Mechatronics Application Project	4
13.	ORI 102	College Success Strategies	2
14.	MAT 165	Trigonometry	3
15.	PHY 150	Applied Physics	4
16.	COM 121	English Composition	3
17.	IFT 110	Microcomputer Applications	3
18.	NET 105	Installation and Maintenance of PC Operating Systems	3
19.	COM 141	Technical Writing	3
20.	ENV 130	The Environment	3
21.	SOC 125	The Individual and Society	3
22.	- - - -	Humanities Elective	3
23.	**- - - -**	**TOTAL ASSOCIATE DEGREE CREDITS and HOURS**	**70**

Revised: 11/15/2013

PMMI Mechatronics Certificate Program

PMMI is a trade association whose member companies manufacture packaging, processing, related converting machinery and machinery components. Its members are part of the supply chain of the many manufacturers that package their products before moving them to their customers.

PMMI's Mechatronics Certificate Program is endorsed by the Manufacturing Institute through its Skills Certification Systems. The Manufacturing Institute is an affiliate of the National Association of Manufacturers and is committed to delivering leading edge information and services to the nation's manufacturers. The Institute focuses on developing human capital strategies through education reform and workforce development.

PMMI's Mechatronics Certificate Program evaluates apprentices for the core technical skills needed in today's manufacturing environment. Through a series of assessments that are based on industry-developed competencies, both new and incumbent workers, entry level operator through technician, can demonstrate the skills needed for high growth, technology intensive manufacturing jobs.

PMMI Core Certificates include:

- Industrial Electricity I and II
- Programmable Logic Controllers I and II
- Fluid Power
- Mechanical Components I and II
- Motors and Motor Control

CERTIFICATE DETAILS

PMMI's Core Certificates in Mechatronics provide a series of assessments that are based on industry developed competencies and can be used to align on-the-job learning and related technical instruction with job requirements. The following competencies provide the apprentice with a series of check lists that document progress in skill attainment and enable the apprentice to develop the required competencies to achieve satisfactory job performance. The partnering company will determine when the apprentice satisfactorily completes all competency requirements. PMMI Certificates are earned upon completion of paper-and-pencil and hands-on competency examinations. The intent is to demonstrate a level of competency and proficiency equivalent to the company's journeyworker-level employee, which can be best attained by aligning on the job learning with classroom theoretical and hands-on lab simulations.

At this writing, Certificates are available in Industrial Electricity Levels I and II, Programmable Logic Controllers Level I, Fluid Power Level I, and Mechanical Components Level I. These are at the core of the Standards of Apprenticeship for Mechatronics Technicians. Certificates in Programmable Logic Controllers Level II, Fluid Power Level II, Mechanical Components Level II, Motors and Motor Control, and Robotics and Motion Control are in development but included here by reference. Educational providers are encouraged to include these skills in curriculum development in anticipation of the completion of certificate development.

INDUSTRIAL ELECTRICITY LEVEL I CERTIFICATE

This certificate covers basic safety practices for voltages up to 600 volts and knowledge of voltage, current and power in AC and DC circuits, circuit analysis of series and parallel loads, and basic understanding of resistors, capacitors, and inductors. Apprentices should be able to interpret and troubleshoot circuits used for lighting, across the line three (3) phase motor starting, and simple relay logic with devices such as control transformers, fuses and circuit breakers, pushbuttons and selector switches, pilot lights and alarm devices, solenoids, three (3) phase motor starters, motor overloads, limit switches, and combinations of control relays to perform basic logic functions. Apprentices should be familiar with simple wiring practices for using these devices and with component level troubleshooting of these devices.

INDUSTRIAL ELECTRICITY COMPETENCIES (Level 1)

Electricity and Electrical Circuits

- ☐ Describe the two types of electrical current and give an application of each
- ☐ Describe the function of the four (4) basic components of an electric circuit
- ☐ Describe the operation of two (2) types of power supplies and give their schematic symbols
- ☐ Describe the function of an electrical schematic
- ☐ Describe the operation of a manual switch that controls Normally Open (NO) and Normally Closed (NC) contacts and give the symbol that represents the component
- ☐ Describe the function of a switch that controls an output device and draw a circuit that represents it and contains the correct symbols
- ☐ Describe the operation of five (5) types of electric output devices and give their schematic symbols

Measuring Voltage, Current and Resistance

- ☐ Define voltage and give its units of measurement
- ☐ Describe how to connect a voltmeter in a circuit to correctly measure voltage
- ☐ Describe how voltage works in series and parallel circuits
- ☐ Define current and give its units of measurement
- ☐ Describe how to use an ammeter to measure current
- ☐ Describe the current characteristics in series and parallel circuits
- ☐ Define resistance and give its units of measurement
- ☐ Describe how resistance and continuity is measured in series and parallel circuits
- ☐ Describe how a voltage drop is measured in a series and parallel circuit
- ☐ Describe how to measure amperage in a series and parallel circuit
- ☐ Describe how to measure resistance of a single component
- ☐ Measure the resistance in series and parallel circuits

Power and Circuit Protection in Series and Parallel Circuits

- ☐ Describe how Ohms law is used to calculate values of an electrical circuit
- ☐ Describe how Krichhoffs is used for the calculation of values in an electrical circuit
- ☐ Define power and give its units of measurement
- ☐ State a formula for calculating the total power used in an electrical circuit

- ☐ State Kirchhoff's Current Law and give an application
- ☐ State a formula for calculating total parallel resistance
- ☐ Describe the function of two types of circuit protection and give an application of each
- ☐ Describe the operation of a fuse and give its schematic symbol
- ☐ Describe the operation of two types of circuit breakers and give their schematic symbols
- ☐ Calculate series resistance given each load's resistance
- ☐ Use Ohm's Law to calculate voltage, current, and resistance in a series circuit
- ☐ Calculate the total power used by a series circuit
- ☐ Calculate the main line current in a parallel circuit
- ☐ Calculate the total parallel resistance
- ☐ Calculate the total power used in a parallel circuit

Electromagnetism, Inductance and Capacitance and their Application

- ☐ Define inductance and give its units of measurement
- ☐ Describe the effect of an inductor in a DC circuit and give an application
- ☐ Describe the effect of an inductor in an AC circuit and give an application
- ☐ Define capacitance and give its units of measurement
- ☐ Describe the operation of a capacitor and give its schematic symbol
- ☐ Describe the effect of the three types of capacitive circuits
- ☐ Describe the effect of a capacitor in an AC circuit and give an application
- ☐ Describe the function of capacitors and inductors in electric power supplies

Combination Circuits

- ☐ Describe how to identify a series and parallel circuit
- ☐ Describe the function of a variable resistor and give an application

Basic Circuits and Troubleshooting

- ☐ Describe how to find a short in an electrical circuit
- ☐ Describe the three (3) basic steps for troubleshooting an open circuit
- ☐ Locate a short circuit
- ☐ Locate an open circuit

Transformers

- ☐ Describe how control transformers are applied in industrial circuits
- ☐ Describe the relationship between input and output current, voltage, power, and turns ratio for a control transformer
- ☐ Describe how to troubleshoot a transformer
- ☐ Describe how to connect and operate control transformers with multi-voltage taps

Introduction to 3-phase motors

- ☐ Describe the operating data on motor and transformer nameplates and the identification, marking and connection of their leads
- ☐ Describe the basic characteristics of 3–phase AC electricity including grounded and ungrounded conductors, neutral, ground and wye and delta systems
- ☐ Describe the use of overcurrent protection and disconnect devices in 3-phase circuits
- ☐ Describe why power transformers are used in industrial and commercial systems
- ☐ Describe the safety procedures for working with 3-phase systems

Manual Motor Control and Protection

- ☐ Describe the purpose and function of manual, 2 wire, and 3 wire motor control
- ☐ Describe the protective functions of a motor starter and the sizing of fuses and overloads

Electrical Control Ladder Logic

- ☐ Describe the structure and organization of a basic control system
- ☐ Describe JIC and IEC symbols and standards for industrial electrical documentation
- ☐ Describe the logical operations of AND, OR, NOR, NAND, NOT, and MEMORY in hard-wired systems
- ☐ Apply inputs, outputs and logic to perform control functions
- ☐ Describe control relay components, function and operation
- ☐ Describe operation and function of various control circuits including 2 wire and 3 wire control
- ☐ Describe methods of testing various industrial electrical control component including pilot devices, relays, transformers and motors
- ☐ Describe methods of analyzing symptoms and troubleshooting systems of industrial electrical components

Basic Electrical Wiring and Construction

- ☐ Describe how wire is sized for an application
- ☐ Describe the function of the National Electrical Code
- ☐ Describe two factors to consider when sizing wire for an application
- ☐ Describe how a three wire AC power cord works
- ☐ Calculate line drop
- ☐ Size wire for an application
- ☐ Describe the three factors that determine the number of wires that can be installed in conduit
- ☐ Describe the function and operation of a 3-way switch
- ☐ Describe the function of an electrical outlet
- ☐ Describe two common methods for splicing wires when it is permissible
- ☐ Determine the number of wires that can be installed in one conduit
- ☐ Connect the wiring system to the service

Control Relays and Pilot Devices

- ☐ Describe the function of a control relay and give an application
- ☐ Describe the operation of a control relay and give its schematic symbol
- ☐ Describe the operation of two types of control relays and give an application of each
- ☐ Describe how detached symbology is used to show a control relay on a ladder diagram
- ☐ Describe the operation of memory logic and give an application
- ☐ Describe the operation of a magnetic motor starter
- ☐ Describe the operation of a two-wire motor control circuit and give an application
- ☐ Describe the operation of a three-wire motor control circuit and give an application
- ☐ Describe the function of a push-to-test pilot light and give an application
- ☐ Describe the operation of a push-to-test pilot light and give its schematic symbol

Introduction to Control Component Troubleshooting

- ☐ Describe two levels of troubleshooting and give an application of each
- ☐ Describe three methods of testing components and give an application of each

- ☐ Describe how to test an indicator lamp
- ☐ Describe how to test a manual switch
- ☐ Describe how to test a control relay
- ☐ Describe how to test a motor contactor
- ☐ Describe how to test an overload relay
- ☐ Describe how to test a 3-phase motor

Safety

- ☐ Describe the process of Lockout/Tagout as a safe work practice
- ☐ Understand the general requirements of the NFPA 70E standard as it relates to industrial electrical hazards in the workplace.
- ☐ Understand the necessary equipment and safety considerations to prevent Electrical Shock in the workplace.

INDUSTRIAL ELECTRICITY LEVEL II CERTIFICATE

The Industrial Electricity II Certificate builds upon the Industrial Electricity I certificate. Apprentices should understand more complex motor starting circuits such as jogging, hand-off-automatic, reversing, and reduced voltage starting. Apprentices should also be familiar with time-based, count-based and sequential control of multiple output loads utilizing control relay logic and automatic input devices such as limit, flow and pressure switches to provide feedback. Apprentices should understand basic electro-fluid power circuits where relay logic is used to operate devices such as pneumatic or hydraulic cylinders through electrically piloted directional control valves. Basic understanding of the various types of electronic sensors, timers and counters used in industrial control is required. Apprentices should be familiar with the sizing and installation of various types of electrical conductors and raceways used in or around industrial machinery and should be able to properly wire an industrial control panel. Finally, candidates should understand basic troubleshooting techniques and practices, not only for the individual components but also for systems of components.

This Certificate is aimed at skilled technicians working relatively independently in the assembly, test, startup, troubleshooting, maintenance, repair or upgrade of electro-mechanical machines or systems. It should be a prerequisite for technicians wishing to move on to industrial machines controlled by PLC's or to industrial machines utilizing velocity, acceleration or other motion control techniques.

INDUSTRIAL ELECTRICITY II
ELECTRICAL SYSTEMS TROUBLESHOOTING COMPETENCIES

Electricity and Electrical Circuits

- ☐ Describe a six (6) step troubleshooting sequence
- ☐ Describe four (4) methods of systems level troubleshooting and give an advantage of each
- ☐ Describe five (5) types of in-circuit component tests

Practice of Troubleshooting

- ☐ Use the symptom and cause troubleshooting method to isolate a bad component
- ☐ Use the output-back troubleshooting method to isolate a bad component
- ☐ Use the half-split troubleshooting method to isolate a bad component
- ☐ Use the shotgun troubleshooting method to isolate a bad component
- ☐ Troubleshoot a two-wire control system
- ☐ Troubleshoot a three-wire control system

Reversing and Jogging Motor Control

Reverse motor control

- ☐ State the National Electrical Manufacturers Association (NEMA) and International Electrotechnical Commission (IEC) standard for reversing the rotation of a three-phase motor
- ☐ Describe the function and operation of a reversing magnetic motor starter
- ☐ Describe the function and operation of a drum switch

Jogging

- ☐ Describe the operation of two (2) types of motor jogging circuits

Hands-Off-Automatic (HOA)/Manual Auto

- ☐ Troubleshoot a control circuit which has manual and automatic modes
- ☐ Describe the operation of a Hand-Off-Automatic motor control circuit

Automatic Input Devices

Components

- ☐ Describe the operation of a limit switch and give its schematic symbol
- ☐ Describe the operation of a float switch and give its schematic symbol
- ☐ Describe the operation of a pressure switch and give its schematic symbol
- ☐ Motor Thermal Overload

Applications

- ☐ Describe the operation of a pump control circuit
- ☐ Describe how to test an automatic input switch
- ☐ Design an overhead door motor control circuit

Timer Control Functions

On-Delay

- ☐ Describe the operation of an On-Delay timer relay and give its schematic symbol
- ☐ Troubleshoot an On-Delay timer circuit

Off-Delay

- ☐ Describe the operation of an Off-Delay timer relay and give its schematic symbol
- ☐ Troubleshoot an Off-Delay timer circuit

Timer Control Functions (CONTINUED)

One-Shot

- ☐ Describe the operation of a one-shot timer and give an application
- ☐ Troubleshoot a timed one-shot motor control circuit

Repeat

- ☐ Describe the operation of a repeat cycle timer and give an application

General

- ☐ Describe how to test a timer relay
- ☐ Design a control circuit to perform an unloaded start of a motor

Solenoid Activated Valves

- ☐ Describe the function of a power diagram
- ☐ Describe the function of electro-hydraulic controls and give an application
- ☐ Describe the operation of two (2) types of solenoid-operated pneumatic DCVs (1 or 2 coils)
- ☐ Connect and operate a relay to energize a fluid power solenoid

Control Relays

General/Components

- ☐ Describe the operation of an electromechanical relay and give its ladder diagram symbol
- ☐ Describe the construction of a general purpose relay and give an application
- ☐ Describe the operation of a relay to perform control logic

Application

- ☐ Describe the function of a seal-in circuit

Sequential Control

Simple

- ☐ Describe the function of a limit switch and give an application
- ☐ Describe the operation of limit switch in an event sequencing circuit
- ☐ Describe the operation of a continuous-cycle reciprocation circuit
- ☐ Connect and operate a continuous-cycle cylinder reciprocation circuit

Sequential Control (CONTINUED)

Complex

- ☐ Describe how multiple cylinders are controlled with multiple limit switches and give an application
- ☐ Design a logic circuit that uses a limit switch to sequence an event
- ☐ Describe the operation of a sequence control circuit
- ☐ Troubleshoot a sequence control circuit (including limit switches, relays, timers and counters)

Introduction to Electronic Sensors

Photo

- ☐ Describe the operation of a photoelectric sensor and give an application
- ☐ Connect and operate a photoelectric sensor

Inductive

- ☐ Measure and analyze inductive sensor performance

Hall Effect

- ☐ Describe the operation of a Hall Effect Sensor and give an application

Capacitive

- ☐ Connect and operate a capacitive sensor

General

- ☐ List five (5) advantages of electronic sensors and two (2) disadvantages

Counters

- ☐ Describe the operation of an upcounter and give its ladder diagram symbol
- ☐ Describe the operation of a downcounter and give its ladder diagram symbol

Electrical Control System Wiring

Blueprint Reading

- ☐ Describe the function of an electrical print
- ☐ Interpret an electrical print

Electrical Control System Wiring (CONTINUED)

Electrical Panel

- ☐ Describe the function of panel wire ways
- ☐ Wire an electrical panel
- ☐ Secure wire bundles in an electrical panel

Color Coding/Wire Numbering

- ☐ Describe the function of wire color coding in electrical control

Terminals and Splicing/Terminal blocks

- ☐ Describe the function of electrical terminal blocks

Wiring/bundling/signal and power

- ☐ Wire an electrical machine

Raceways and Conduits

Construction Techniques

- ☐ Deburr conduit/reaming
- ☐ Calculate conduit length given an application

Components

- ☐ Describe the function of conduit and list five (5) types
- ☐ Describe the similarities and differences between intermediate metallic and rigid conduit

General

- ☐ Describe the function of a wiring system

Conductors, Disconnects and Overcurrent Protection

Determining conductor sizing/insulation and length

- ☐ Define conductor ampacity and describe the physical characteristics that affect it.
- ☐ Describe how distance affects wire selection

Disconnects

- ☐ Describe how to size a disconnect

Overcurrent Protection

- ☐ Describe the function of overcurrent protection and list two (2) types

Counters

- ☐ Describe the operation of an upcounter and give its ladder diagram symbol
- ☐ Describe the operation of a downcounter and give its ladder diagram symbol.

Control Transformers

Describe how to connect and operate control transformers with multi-voltage taps

- ☐ Describe the function of a tap on the secondary of a transformer and give an application

Describe how to troubleshoot a transformer

- ☐ Troubleshoot a transformer by measuring continuity

Describe the relationship between input and output current, voltage, power, and turns ratio for a control transformer

- ☐ Describe how to calculate the output voltage of a transformer
- ☐ Describe how control transformers are applied in industrial circuits
- ☐ Describe the operation of a control transformer and give its schematic symbol

Power Transformers

Describe the operating data on transformer nameplates and the identification, marking and connection of their leads

- ☐ Describe the operating data on a transformer's nameplate

Describe the basic characteristics of 3-phase AC electricity including grounded and ungrounded conductors and wye and delta systems

- ☐ Describe the two (2) most common 3-phase voltage systems

Describe the use of overcurrent protection and disconnect devices in 3-phase circuits

- ☐ Explain why time-delay fuses are used with motor starting circuits

Describe why power transformers are used in industrial and commercial systems

- ☐ Isolation transformers

Grounding

- ☐ Explain the importance of the equipment ground connection

Electrical Safety

70E

- ☐ FRC – Fire Retardant Clothing requirements /laundry requirements
- ☐ PPE Requirements – Clothing FRC, Cal/cm^2, Arc Flash Face Shield, Gloves, Shoes
- ☐ Boundaries – Limited approach, Flash Protection Boundary

System Safety

- ☐ Describe function of safety relay in a relay circuit
- ☐ Describe function of interlock system
- ☐ Master control master control relay (MCR)
- ☐ List 10 (ten) basic rules of electrical safety
- ☐ Describe the purpose of the lockout/tagout system used in industry
- ☐ Perform a lockout/tagout

Describe how to verify all power is eliminated from the machine (specifically air)

PROGRAMMABLE LOGIC CONTROLLERS (PLC'S) LEVEL I CERTIFICATE

This certificate covers the principles and applications of different types of logic and programming used to control packaging machinery and systems. Topics include hardware and software composition of control systems, input/output interfacing, basic logic commands and common programming instructions. There is additional emphasis on common program tasks, and troubleshooting PLC based systems.

Knowledge of relay logic, ladder programming and input/output devices is needed to understand and maintain all types of common packaging equipment.

This certificate is aimed at entry level technicians who may be involved in the assembly, test, startup, troubleshooting, maintenance, repair or upgrade of basic packaging machinery modules.

PROGRAMMABLE LOGIC CONTROLLERS (PLC'S) LEVEL I COMPETENCIES

Operation of a PLC

- ☐ Describe the function of a programmable logic controller and give an application
- ☐ List advantages of a PLC
- ☐ Describe the functions of the basic components of a PLC
- ☐ Describe the basic operation of a PLC
- ☐ Describe how I/O modules communicate with the PLC processor

Memory Organization and addressing

- ☐ Recognize languages used to program a PLC
- ☐ Identify the function and purpose of a tag
- ☐ Identify a memory map (register map, I/O map)
- ☐ Identify the difference between physical and logical input/output addressing
- ☐ Describe how PLC module terminals are referenced by tag names

Discrete I/O Interfacing

- ☐ Describe features used to select a PLC discrete input module
- ☐ Describe features used to select a PLC discrete output module
- ☐ Explain how to interface a sensor with a sink or source input
- ☐ Explain how to interface a device with a sink or source output
- ☐ Identify the uses of a relay output, transistor and triac

- ☐ Describe how to interface a PLC to a machine controller

Discrete I/O Interfacing (CONTINUED)

- ☐ Connect and test a limit switch to a discrete input module
- ☐ Connect and test the operation of a solenoid valve to a PLC output
- ☐ Connect and test the operation of an electronic sensor to a PLC input module
- ☐ Connect and test the operation of a PLC input module to a robot output module
- ☐ Connect and test the operation of a PLC discrete output module to a robot input module
- ☐ Develop an interface wiring diagram to interface a PLC to a machine controller
- ☐ Describe the function and operation of input/output diagrams

Function and Use of Monitoring Devices

- ☐ Describe the function and basic operation of serial communication and give an example
- ☐ Describe how to set-up a serial communications driver
- ☐ Online program editing
- ☐ Offline program editing
- ☐ Online program monitoring
- ☐ Program documentation (printing and saving)
- ☐ Diagnosing malfunctions
- ☐ Troubleshooting control systems
- ☐ Running and stopping PLC
- ☐ Software/Hardware compatibility
- ☐ Name methods of entering a PLC program and give an advantage of each
- ☐ Open a PLC program
- ☐ Download a PLC processor file using PLC programming software
- ☐ Upload a PLC processor file using PLC programming software
- ☐ Monitor PLC operation using PLC programming software

Basic PLC Logic Instructions

- ☐ Describe the operation of normally open and normally closed input instructions
- ☐ Know the operation of an output instruction
- ☐ Describe the basic operation of PLC ladder logic (AND/OR/NOT/NAND)

- ☐ Recognize different types of numbering systems and explain their importance
- ☐ Describe the operation of the Decimal numbering system and give an application
- ☐ Describe the operation of the Binary numbering system and give an application

Basic PLC Logic Instructions (CONTINUED)

- ☐ Convert between Decimal and Binary
- ☐ Identify the purpose of a PLC project
- ☐ Describe how an input device can reference multiple input instructions
- ☐ Describe how input device logic affects input instruction logic
- ☐ Describe how a PLC controls multiple outputs at the same time

PLC Timer and Counter Instructions

- ☐ Demonstrate an understanding of Time Base
- ☐ Describe the function of retentive and non-retentive PLC timing instructions and give an application of each
- ☐ Describe the operation of a retentive timer on-delay instruction
- ☐ Describe the function and application of two (2) types of non-retentive timer instructions (on delay and off delay)
- ☐ Describe the operation of the non-retentive timer on-delay instruction
- ☐ Describe the operation of an off-delay timer instruction
- ☐ Define time-driven sequencing and give applications
- ☐ Describe the operation of a time-driven sequence program
- ☐ Enter and edit a PLC program that uses an retentive timer on (RTO) instruction
- ☐ Enter and edit a PLC program that uses a non-retentive timer on (TON) instruction
- ☐ Enter and edit a PLC program that uses a non-retentive timer off (TOF) instruction
- ☐ Design a PLC program that provides low voltage starting of an electric motor
- ☐ Design a PLC program that controls a centrifugal air compressor
- ☐ Describe the functions of PLC counter instructions
- ☐ Describe the operation of a Count Up instruction
- ☐ Describe the operation of a countdown instruction
- ☐ Describe Counter Reset
- ☐ Describe Timer Reset
- ☐ Enter and edit a PLC program that uses a Count Up instruction

- ☐ Design a PLC program to indicate when preventive maintenance should be performed
- ☐ Enter and edit a PLC program that uses an Up/Down Counter instruction
- ☐ Design a PLC program that controls an adjustable counting station

Basic PLC Motor control applications

- ☐ Describe methods by which a PLC can be used to start and stop a motor
- ☐ Identify a PLC input/output diagram for a motor application
- ☐ Describe how input instructions can be controlled by PLC output instructions
- ☐ Describe the function and operation of PLC seal-in and latch logic
- ☐ Describe the function and operation of a program interlock and give an application
- ☐ Describe how a program interlock is used for safety
- ☐ Design a PLC program to jog a motor
- ☐ Design a PLC program to control the start/stop of a bi-directional motor
- ☐ Design a PLC program to interlock two motors
- ☐ Design a PLC program that uses a safety interlock to control the operation of a machine

Basic PLC Sequencing Applications

- ☐ Define event-driven sequencing
- ☐ Describe the operation of a pick and place PLC program
- ☐ Describe the operation of a continuous pick and place PLC program
- ☐ Describe the operation of a basic multiple actuator sequence program
- ☐ Design a reciprocating actuator sequence PLC program
- ☐ Design a continuous cycle clamp and drill sequence PLC program
- ☐ Troubleshoot a clamp and drill sequence PLC program

Basic PLC Machine Application

- ☐ Describe the steps used to design a controller program
- ☐ Describe the operation of a PLC program with manual and automatic modes
- ☐ Describe methods of stopping a PLC-controlled machine
- ☐ Describe the application of timers and counters in industrial control
- ☐ Design a PLC program (case studies and/or examples)
- ☐ Troubleshoot a PLC program with manual and automatic modes
- ☐ Design a motor control program which uses both manual and automatic modes
- ☐ Design a PLC program which has both Halt and Cycle-Stop functions

- ☐ Troubleshoot a PLC program which has both Halt and Cycle-Stop functions
- ☐ Design a PLC program to control the number of production cycles
- ☐ Design a PLC program to control a piston filler machine
- ☐ Troubleshoot a PLC program which controls a piston filler machine

Troubleshooting PLC Based Systems

- ☐ Describe hardware and software troubleshooting and give an application of each
- ☐ Define components of a PLC system
- ☐ Describe the functions of PLC status and diagnostic indicators
- ☐ Describe the operation of the master control relay circuit to the PLC
- ☐ Describe how to troubleshoot master control relay (MCR) power problems
- ☐ Describe how to troubleshoot a PLC chassis power supply
- ☐ Describe how to test PLC discrete input devices
- ☐ Describe how to test a PLC discrete input module
- ☐ Describe the Force function and give an application
- ☐ Describe how to test a PLC discrete output device
- ☐ Describe how to test a PLC discrete output module
- ☐ Use PLC status indicators to determine the status of PLC operation
- ☐ Troubleshoot PLC power supply problems
- ☐ Test a PLC discrete input device
- ☐ Test a discrete input module
- ☐ Use the Force Function to force an input or output
- ☐ Use the Force function to test a PLC discrete output device
- ☐ Test a PLC discrete output module

Troubleshooting PLC Hardware and Software

- ☐ Describe how to troubleshoot a PLC processor which controls local I / O
- ☐ Describe methods of PLC troubleshooting and give an application of each
- ☐ Describe four types of PLC component tests
- ☐ Describe a systematic PLC troubleshooting sequence
- ☐ Describe the function of project documentation and give an application
- ☐ Troubleshoot a processor fault

- ☐ Use a six-step sequence to troubleshoot a PLC system
- ☐ Troubleshoot a PLC-controlled electric motor system
- ☐ View project documentation and use it to operate a PLC project
- ☐ Document a PLC program file
- ☐ Scenario-find a fault or solution

PROGRAMMABLE LOGIC CONTROLLERS (PLC'S) LEVEL II CERTIFICATE

This certificate covers advanced principles and applications of Programmable Logic Controllers (PLC's) and familiarizes apprentices with a more advanced PLC's. The apprentice has the option of working with the Rockwell/Allen-Bradley ControlLogix System or the Siemens S7 system. The apprentice should discuss the selection with his/her Apprentice Supervisor. Among the advanced topics are PLC real time considerations, various levels of PLC networking, alternate programming languages for PLC's, international standards applied to PLC's, integration of logic and motion control in PLC's, integration of process control in PLC's, advanced Human Machine Interface (HMI) for PLC's, Supervisory Control and Data Acquisition (SCADA) with PLC's, alarm management, batch control, power failure strategies, and process safety.

This certificate covers the advanced applications of PLC's that prepares the apprentice to support and maintain PLC systems in most any discrete, hybrid or continuous industrial environment.

PROGRAMMABLE LOGIC CONTROLLERS (PLC'S) LEVEL II COMPETENCIES

- ☐ Demonstrate the ability to use a laptop and desktop computer and appropriate software to configure, connect, monitor, run, stop, and program a PLC
- ☐ Demonstrate the ability to load, save, store, print and edit a PLC program
- ☐ Demonstrate the ability to implement a PLC job using the appropriate PLC's file or project structure
- ☐ Convert between binary, decimal, binary coded decimal, octal, two's complement and hexadecimal number systems
- ☐ Describe integer, floating point, binary coded decimal (BCD), signed, unsigned, American Standards Code for Information Interchange (ASCII), and Boolean data types
- ☐ Describe the memory organization, the register and image table organization, the allowable data types, and the creation and use of tags for the appropriate PLC
- ☐ Define insertion delay, output response, scan time, throughput and jitter
- ☐ Describe the PLC processes instructions, inputs, outputs and communications tasks
- ☐ Explain how various processing tasks affect throughput
- ☐ Explain how to select and configure digital, analog and special purpose inputs/outputs
- ☐ Explain how input/output response time affects control of a machine or process
- ☐ Describe the impact of leakage currents and loading on PLC inputs/outputs

- ☐ Demonstrate the ability to design and implement circuits to interface electronic devices with sinking and sourcing inputs/outputs
- ☐ Create a program to measure processor scan time
- ☐ Create a system to measure processor throughput
- ☐ Compare throughput and jitter for various I/O configurations and programming situations
- ☐ Explain how scan time, throughput and jitter affect machine and process control
- ☐ Describe the symbols used in both Joint Industry Council (JIC) and International Electrotechnical Commission (IEC) circuit diagrams
- ☐ Convert between JIC and IEC circuit diagrams
- ☐ Use both JIC and IEC circuit diagrams to troubleshoot PLC systems
- ☐ Explain how to ensure machine and operator safety in the event of a PLC failure, a power failure or an unexpected loss of some or all input signals or output response
- ☐ Describe the conditions and procedures for replacing input/output cards
- ☐ Determine when and how to replace input/output cards under power or during operation
- ☐ Describe the precautions and use of force functions
- ☐ Explain how to locate forced elements
- ☐ Demonstrate the use of the available software diagnostic troubleshooting aids for the appropriate PLC
- ☐ Describe the use of the available troubleshooting displays and indicators for the appropriate PLC
- ☐ Demonstrate the ability to test, configure and replace PLC inputs/outputs, power supplies, batteries, processors, chassis and cables
- ☐ Describe the operation of advanced relay ladder logic, timer, counter, and sequencing instructions
- ☐ Describe the operation of advanced math and data move instructions
- ☐ Describe the operation of advanced program control instructions
- ☐ Describe the programming language options available for the appropriate PLC, the applicability of each and the relationship to international standard IEC61131
- ☐ Develop programs for the appropriate PLC using each of the available programming languages

- ☐ Describe the issues of single and differential input, shielding, sensitivity, resolution, accuracy, sample rate, filtering and scaling associated with the use of analog inputs/outputs
- ☐ Demonstrate the ability to install, configure, program, scale, operate, display and troubleshoot analog input/output devices with the appropriate PLC
- ☐ Describe the options and tradeoffs for implementing proportional integral derivative (PID) control in the appropriate PLC
- ☐ Demonstrate the ability to operate and troubleshoot a PID loop in a PLC
- ☐ Describe the operation and function of device level networking
- ☐ Demonstrate the ability to construct, configure, program, operate and troubleshoot a device level network with the appropriate PLC (DeviceNet or Profibus)
- ☐ Describe the operation and function of a control or cell level network
- ☐ Demonstrate the ability to construct, configure, program operate and troubleshoot a control level network
- ☐ Describe the application of PLC's and Human Machine Interfaces (HMIs) in one-to-one, one-to-many, many-to-one and many-to-many configurations
- ☐ Program a PC graphical HMI and a PLC to create a one-to-many topography using one graphical display and two (2) PLC's
- ☐ Program a PC graphical HMI and a PLC to create a one-to-many topography using one graphical display and two (2) PLC's
- ☐ Describe the importance and function of alarm management
- ☐ Describe the use and importance of graphic libraries and display standards when working with PLC's and HMIs
- ☐ Demonstrate alarm management techniques in a one to many configuration
- ☐ Describe how control can be affected by display and communications functions
- ☐ Describe the operation and function of area-wide networking with a PLC
- ☐ Demonstrate the ability to construct, configure, program, operate and troubleshoot an area-wide network using an Ethernet Local Area Network (LAN) with the appropriate PLC
- ☐ Describe the operation and function of integrating single and multi-axis coordinated motion control in a PLC
- ☐ Describe the purpose and function of a motion network

- ☐ Demonstrate the ability to operate and troubleshoot a multi-axis motion control application using a PLC and a motion control network

Note: Wherever the term “appropriate PLC” is used, the reader may substitute “ControlLogix PLC” or “S7 PLC”.

FLUID POWER LEVEL I CERTIFICATE

This certificate covers the function, operation, and application of common components used in fluid power circuits and systems. It also assesses the understanding of how fluid power components and accessories are placed together to create circuits and systems for powering industrial machines. The major emphasis is on pneumatics with a lesser emphasis on hydraulics and vacuum systems. Electro-fluid power troubleshooting is emphasized. Topics include: Circuits and logic, compressors and conditioners, connectors, directional control valves, electro-fluid power, filters, fittings, flow control and relief valves, gages and instruments, hoses, lubricators, metal tubing, motors, pressure sequence valves, pump and reservoir, regulators, safety, theory, threaded pipe, troubleshooting and testing, and vacuum.

This Certificate is intended for entry-level technicians who will be involved in the application, installation, and modification or troubleshooting of Fluid Power systems.

FLUID POWER LEVEL I COMPETENCIES

Actuators

- ☐ Describe the operation of a double-acting pneumatic cylinder and give its schematic symbol
- ☐ Describe the function of a single-acting pneumatic cylinder and give an application
- ☐ Describe how cylinder sizes are specified, Size a pneumatic cylinder given a load, and Describe how to size a pneumatic cylinder
- ☐ Describe five (5) common tie rod cylinder mounting styles and give an application of each
- ☐ Select a cylinder mounting style for a given application
- ☐ Describe the operation of a quick exhaust valve and give its schematic symbol
- ☐ Describe six (6) symptoms of pneumatic cylinder failure
- ☐ Describe the function of a rotary actuator and give an application
- ☐ Describe the function of a shock absorber
- ☐ Describe how to troubleshoot slow actuator speed
- ☐ Calculate the extension force of a cylinder given its size and pressure

Best Practices

- ☐ Describe the importance of eliminating air leaks
- ☐ Describe four (4) common pneumatic component failures and their probable causes

- ☐ Give five (5) guidelines used in the construction of pneumatic circuits

Circuits and Logic

- ☐ Describe the function of a pneumatic schematic
- ☐ Describe the line symbols used with fluid power circuits
- ☐ Design speed control circuits
- ☐ Design a pneumatic circuit that uses an externally air-piloted directional control valve (DCV)
- ☐ Define air logic and give four (4) applications
- ☐ Describe the function of a shuttle valve and give an application
- ☐ Connect and operate an air logic circuit to control a reciprocating cylinder
- ☐ Connect a hydraulic circuit given a schematic

Compressor and Conditioners

- ☐ Explain how air pressure is created in a pneumatic system
- ☐ Describe the function of a dryer and give an application
- ☐ Describe the operation of a refrigeration type air dryer
- ☐ Describe the principle of operation of three (3) types of dryers and give an application of each
- ☐ Describe the function of pneumatic system trap
- ☐ Describe the operation of two (2) types of pneumatic traps and give the schematic symbol of each

Connectors

- ☐ Describe the function of a pneumatic quick connect fitting and give its schematic symbol
- ☐ Describe the function of a tee and give its schematic symbol
- ☐ Describe the function of a hydraulic quick disconnect fitting and give its schematic symbol

Direction Control Valves

- ☐ Describe the function of a 5-way, 3-position pneumatic DCV and give an application
- ☐ Describe the operation of a 5-way, 3-position pneumatic DCV and give its schematic symbol
- ☐ Describe the function of a 3/2 pneumatic DCV and give an application
- ☐ Connect and operate a pneumatic cam-operated 3/2 DCV

- ☐ Describe the operation of a 3/2 pneumatic DCV and give its schematic symbol
- ☐ Describe the function of a pneumatic cam-operated valve and give an application
- ☐ Describe the operation of a pneumatic cam-operated DCV and give its schematic symbol

Direction Control Valves (CONTINUED)

- ☐ Describe the function of an externally air-piloted DCV and give an application
- ☐ Describe the operation of an externally air-piloted DCV and give its schematic symbol
- ☐ Describe the function of a pilot-operated DCV and give an application
- ☐ Describe the operation of internal and external DCV pilots of a pilot-operated DCV
- ☐ Describe the function of internal and external DCV pilots
- ☐ Describe the symptoms of pilot-operated DCV failure and their causes
- ☐ Describe how to inspect and troubleshoot a pilot-operated DCV
- ☐ Describe the operation of a 3-position, 4-way DCV and give an application
- ☐ Describe the operation of a 3-position, 4-way DCV and give its schematic symbol
- ☐ Connect and operate a double-acting cylinder using a 4/3 solenoid-operated hydraulic DCV
- ☐ Connect and operate a double-acting cylinder using a 4/2 solenoid-operated DCV
- ☐ Connect and operate a single-acting cylinder using a 5/2 solenoid-operated pneumatic DCV

Electro-Fluid Power

- ☐ Describe the operation of two (2) types of hydraulic solenoids and explain the application of each
- ☐ Describe the operation of two (2) types of solenoid-operated pneumatic DCVs
- ☐ Describe the operation of a solenoid-operated hydraulic DCV and give its schematic symbol
- ☐ Describe the function and operation of a hydraulic DCV manual override
- ☐ Use the manual override of a solenoid-operated pneumatic DCV to jog a cylinder
- ☐ Use the manual override if a solenoid-operated hydraulic DCV to jog a cylinder
- ☐ Describe the function of electro-pneumatic controls and give an application
- ☐ Describe the function and operation of a pneumatic DCV manual override
- ☐ Describe the function of a limit switch and give an application
- ☐ Describe how to interpret limit switch symbols

- ☐ Describe the operation of a limit switch and give its schematic symbol
- ☐ Describe the operation of limit switch in an event sequencing circuit
- ☐ Describe the operation of a single-cycle cylinder reciprocation circuit

Filters

- ☐ Describe the function of an air filter
- ☐ Describe the operation of an air filter and give its schematic symbol
- ☐ Drain a pneumatic filter
- ☐ Describe two (2) methods of removing water vapor from a pneumatic system
- ☐ Describe four (4) symptoms of filter failure and their causes
- ☐ Describe how to inspect and troubleshoot a filter

Flow Control and Relief Valves

- ☐ Describe the function of a muffler and give its schematic symbol
- ☐ Describe the function of a pneumatic check valve and give an application
- ☐ Describe the operation of three types of check valves and give their schematic symbol
- ☐ Describe the function of a check valve and give an application
- ☐ Connect and operate a check valve
- ☐ Describe the operation of two (2) types of pneumatic check valves and give their schematic symbols
- ☐ Describe the operation of a flow control valve and give its schematic symbol
- ☐ Connect and adjust a flow control valve to control speed of an actuator
- ☐ Describe what determines the speed of a pneumatic actuator
- ☐ Describe the effect of actuator load changes on flow control valve operation
- ☐ Describe the operation of a flow control valve and give its schematic symbol
- ☐ Describe the function of the flow control valve and give an application
- ☐ Troubleshoot a flow control valve using an in-circuit test

Flow Control and Relief Valves (CONTINUED)

- ☐ Describe how to inspect and troubleshoot a flow control valve
- ☐ Describe the symptoms of flow control valve failure and their causes

- ☐ Connect and adjust a flow control valve to control speed of an actuator
- ☐ Describe the operation of a meter-in flow control circuit and give an application
- ☐ Connect and operate a meter-in flow control circuit
- ☐ Describe the operation of a meter-out flow control circuit and give an application
- ☐ Connect and operate an exhaust port speed control circuit
- ☐ Connect and operate a meter-out flow control circuit
- ☐ Describe the operation of an exhaust port speed control and give an application
- ☐ Connect and operate a needle valve to control actuator speed
- ☐ Connect and operate a needle valve to control the speed of an actuator
- ☐ Describe the operation of a needle valve and give its schematic symbol
- ☐ Describe the main function of a pneumatic needle valve and give an application
- ☐ Describe the main function of a needle valve
- ☐ Describe the symptoms of quick exhaust valve failure and their causes
- ☐ Describe how to inspect and troubleshoot a quick exhaust valve
- ☐ Describe the function of an exhaust restrictor and give an application
- ☐ Describe the symptoms of exhaust restrictor failure
- ☐ Describe the operation and construction of a exhaust restrictor
- ☐ Describe the function of a relief valve and give an application
- ☐ Connect and adjust the pressure setting of a pressure relief valve (PRV)
- ☐ Describe the operation of an integral check valve and give its schematic symbol
- ☐ Connect a relief valve in a circuit to limit pressure in the system
- ☐ Describe the operation of a direct-acting relief valve and give its schematic symbol

Gages and Instruments

- ☐ Read a pneumatic pressure gage
- ☐ Read a hydraulic pressure gage
- ☐ Describe how pressure gages are calibrated

Gages and Instruments (CONTINUED)

- ☐ Measure Delta P across pneumatic components
- ☐ Connect and read a manometer

- ☐ Describe the operation of two (2) types of manometers
- ☐ Describe the function of a flowmeter and give an application
- ☐ Connect and read a flow meter
- ☐ Describe the operation of two (2) types of flowmeters and give their schematic symbol
- ☐ Connect and read a flowmeter
- ☐ List and give an advantage of each of three (3) devices used to measure vacuum levels
- ☐ Connect and read a vacuum gage
- ☐ Convert between units of mercury and units of air pressure
- ☐ Convert between units of water column and units of mater pressure

Hoses

- ☐ Describe the three (3) functions of an air line
- ☐ Describe how hose is specified
- ☐ Describe how to determine the length of a hose for an application
- ☐ Identify hose size given a specification
- ☐ Identify hose size by measurement
- ☐ Describe how to cut hose
- ☐ Cut off hose using a cut-off saw
- ☐ Describe how to calculate the pressure drop given hose size and flow rate
- ☐ Calculate the pressure drop given hose size and flow rate
- ☐ Describe how to maintain a hose system

Lubricators

- ☐ Describe the function of air lubrication and list three (3) lubrication methods
- ☐ Describe the operation of three (3) types of pneumatic lubricators and give an application of each
- ☐ Describe the function of a lubricator and give its schematic symbol
- ☐ Describe four (4) symptoms of lubricator failure and their causes
- ☐ Describe how to inspect and troubleshoot a lubricator

Metal Tubing

- ☐ Describe how metal tubing is specified
- ☐ Select and size metal tubing for an application
- ☐ Describe how to select and size metal tubing for a given application
- ☐ Calculate the head loss given metal tubing size and flow rate
- ☐ Describe how to calculate the head loss given metal tubing size and flow rate
- ☐ Write a tubing specification given its dimensions
- ☐ Identify metal tubing given a specification
- ☐ Identify metal tubing specification by measurement
- ☐ Describe four (4) types of metal tubing and give an application of each
- ☐ Describe the operation of a tube bender
- ☐ Use a tube bender to bend tubing to a certain angle
- ☐ Determine bend locations and angles given a tubing layout drawing
- ☐ Describe how to determine bend locations and angles
- ☐ Describe how to use a tube cutter to cut metal tubing
- ☐ Describe three methods of assembling metal tubing
- ☐ Describe how to solder metal tubing
- ☐ Cut, bend and assemble steel tubing using flared and flareless fittings
- ☐ Assemble copper tubing using flared and flareless fittings
- ☐ Describe how to assemble tubing using flared and flareless fittings

Motors

- ☐ Describe the function of a pneumatic motor and give an application
- ☐ Describe how to size a pneumatic motor
- ☐ List three (3) types of hydraulic motors and give an application of each
- ☐ Describe the operation of a hydraulic motor and give its schematic symbol
- ☐ Describe the function of a hydraulic motor and give an application
- ☐ Calculate the air flow needed for a pneumatic motor
- ☐ Select a pneumatic motor
- ☐ List three (3) common pneumatic motor designs and explain where they are used
- ☐ Describe the operation of a pneumatic motor and give its schematic symbol

Motors (MOTORS)

- ☐ Define pneumatic motor torque and give its units of measurement
- ☐ Describe how to use a torque-speed curve to determine pneumatic motor speed
- ☐ Define three (3) types of torque and give its units of measurement
- ☐ Describe four (4) symptoms of pneumatic motor failure
- ☐ Troubleshoot a motor using an in-circuit test
- ☐ Describe how to inspect and troubleshoot a pneumatic motor

Pressure Sequence Valves

- ☐ Describe the function of a pressure sequence valve and give an application
- ☐ Design a two-sequence valve control circuit
- ☐ Design a pressure sequence circuit
- ☐ Connect and operate a pressure sequence circuit
- ☐ Connect and adjust the pressure setting of a sequence valve
- ☐ Explain why a sequence valve is externally drained
- ☐ Describe the function of a two-sequence valve control circuit
- ☐ Describe the function of a by-pass check valve in a sequence valve circuit
- ☐ Describe the operation of a direct-acting sequence valve and give its schematic symbol

Pump and Reservoir

- ☐ Describe the operation of a hydraulic power unit
- ☐ Describe the operation of a fixed-displacement pump and give its schematic symbol
- ☐ Describe the operation of three (3) types of fixed displacement pumps and give an application of each
- ☐ Describe maintenance of a hydraulic power unit

Regulators

- ☐ Describe the operation of a pressure regulator and give its schematic symbol
- ☐ Describe the operation of a pressure regulator under flow conditions
- ☐ Describe the function of a pressure regulator valve and give an application
- ☐ Describe four (4) symptoms of regulator failure and their causes
- ☐ Describe how to inspect and troubleshoot a regulator

- ☐ Describe the operation of a direct-acting pressure relief valve (PRV) and give its schematic symbol

Safety

- ☐ Explain six (6) pneumatic safety rules
- ☐ Describe eight (8) pneumatic troubleshooting safety rules
- ☐ Piping safety test
- ☐ Describe the function of a lockout/tagout system
- ☐ Describe the operation of an electrical lockout/tagout system
- ☐ Describe the operation of a pneumatic lockout/tagout system
- ☐ Perform a lockout/tagout on a pneumatic system
- ☐ Describe seven (7) rules of safe dress for working with piping

Theory

- ☐ Define pneumatic pressure and give its units of measurement
- ☐ Convert between absolute pressure and gage hydraulic pressure
- ☐ Define hydraulic pressure and give its units of measurement
- ☐ Convert between gage and absolute pressures
- ☐ Describe two (2) methods of representing pressure
- ☐ Describe how to calculate the force output of an extending cylinder
- ☐ Describe how to calculate the force output of a hydraulic cylinder in retraction (pull)
- ☐ Describe how to calculate the actual force output of an extending cylinder
- ☐ Calculate the retraction force of a cylinder given its size and pressure
- ☐ Calculate the extension force of a cylinder given its size and pressure
- ☐ Describe how to calculate the force output of a cylinder in retraction (pull)
- ☐ State Pascal's Law and explain its significance in pneumatics
- ☐ State Pascal's Law and explain its significance in hydraulics
- ☐ Explain how force is multiplied using Pascal's Law in pneumatics
- ☐ Explain how force is multiplied using Pascal's Law in hydraulics
- ☐ State Boyle's Law and explain its significance
- ☐ Use Boyle's Law to calculate changes in pressure and volume

- ☐ Explain how a pneumatic system creates air flow
- ☐ Measure Delta P across a hydraulic component

Theory (CONTINUED)

- ☐ Explain how Delta P describes hydraulic resistance
- ☐ Explain how Delta P describes pneumatic resistance and explain its importance
- ☐ Define air flow rate and give its units of measurement
- ☐ Define flow rate and explain how it can be measured
- ☐ Define dew point and relative humidity and explain their importance
- ☐ Explain how water condenses in a pneumatic systems and its effect
- ☐ Define hydraulics and give an application
- ☐ Describe the function of a hydraulic schematic
- ☐ Describe the functions of five (5) basic components of a hydraulic system
- ☐ Define pneumatics and give an application
- ☐ Explain how pressure is distributed in a hydraulic system
- ☐ Describe how to calculate the extend speed of a hydraulic cylinder
- ☐ Calculate the cylinder stroke time given its size and a flow rate
- ☐ Calculate the retract speed of a cylinder given its size and a flow rate
- ☐ Calculate the extend speed of a hydraulic cylinder given its size and a flow rate
- ☐ Describe how to calculate the stroke time of a cylinder
- ☐ Describe how to calculate the retract speed of a cylinder

Threaded Pipe

- ☐ Identify pipe size and type by measurement
- ☐ Write a pipe specification given its dimensions
- ☐ Identify pipe size given a specification
- ☐ Describe the function of a piping schematic drawing
- ☐ Read and interpret a piping schematic drawing
- ☐ Identify the pipe fitting schematic symbols
- ☐ Describe the function of an expansion joint and give an application

- ☐ Install an expansion joint
- ☐ Describe the operation of an expansion joint

Troubleshooting and Testing

- ☐ Describe two (2) levels of pneumatic troubleshooting and give an application of each
- ☐ Define pneumatic troubleshooting and explain its importance
- ☐ Describe two (2) methods of testing a pneumatic component and give an application of each
- ☐ Describe four (4) types of in-circuit component tests and give an application of each
- ☐ Describe three (3) pneumatic troubleshooting measurements and give an application of each
- ☐ Use a pressure test point to check system pressure
- ☐ Describe the construction of a pressure test point and give an application
- ☐ Describe how to interpret a pneumatic troubleshooting chart
- ☐ Describe how to use a flowchart to aid in troubleshooting
- ☐ Describe the construction of a troubleshooting flowchart
- ☐ Describe the function of a troubleshooting flowchart
- ☐ Describe the four methods of system level troubleshooting
- ☐ Describe how to use PLC I/O indicators to troubleshoot a pneumatic system process
- ☐ Troubleshoot a pneumatic system using PLC indicator lights
- ☐ Describe how to troubleshoot zero system pressure
- ☐ Troubleshoot high system pressure
- ☐ Troubleshoot low system pressure
- ☐ Describe how to troubleshoot high system pressure
- ☐ Describe how to troubleshoot low system pressure

Vacuum

- ☐ List two (2) methods used to produce vacuums and give an advantage of each
- ☐ Define a vacuum and give three (3) industrial applications
- ☐ Describe three (3) symptoms of vacuum generator failure and their causes
- ☐ Describe how to inspect and troubleshoot a vacuum generator

- ☐ Describe two (2) symptoms of vacuum cup failure and their causes
- ☐ Describe how to inspect and troubleshoot a vacuum cup
- ☐ Describe the function of an vacuum switch and give an application
- ☐ Describe how to inspect and troubleshoot a vacuum switch

Vacuum (CONTINUED)

- ☐ Describe a symptom of vacuum switch failure
- ☐ Describe the operation of a vacuum switch
- ☐ Describe the function of a vacuum pump and give an application
- ☐ Describe the operation of a reciprocating vacuum pump
- ☐ Describe how to inspect and troubleshoot a vacuum pump

FLUID POWER LEVEL II CERTIFICATE

This certificate covers the fundamentals of process control and instrumentation as applied in industry for the control of level, flow, temperature, and pressure. The concept of a control loop is introduced and each of the loop's components, sensor, controller and final element are examined. Design, documentation, operation, performance tuning and troubleshooting of single loop systems are covered.

The concepts of process control and instrumentation are most often associated with continuous flow industries such as chemical processing and refining, however, as the science of automation and control advances, these concepts are being much more frequently applied across discrete and hybrid industries as well in an effort to keep manufacturing conditions and variables in a more precisely known state. Higher production rates require the continuous monitoring and control of the flow, temperature and pressure of substances including air, water, coolant, lubricant, adhesive, reactants, and ingredients. Knowledge in the area of process control and instrumentation is applicable across the full spectrum of industries. This certificate will provide the Mechatronics Technician with the fundamentals for many of the applications in discrete and hybrid industries such as machining, assembly, food processing and packaging.

FLUID POWER LEVEL II COMPETENCIES

PROCESS CONTROL AND INSTRUMENTATION

- ☐ Describe proper safety procedures for working with process systems
- ☐ Define process control; controlled and manipulated variables; open and closed loop control; manual control; automatic control; transducer; transmitter; converter; controller; final control element; sensor; specific gravity; sensitivity; accuracy; scaling; on/off control; time-proportional control; proportional control; steady state; transient state; upset; integral control; derivative control; proportional band; gain; reset; reset tune; reset rate; wind-up; resolution; accuracy; repeatability; temperature; internal energy; heat transfer; conduction; convection; radiation; thermal power
- ☐ Describe the operation, function and application of level measurement, sight gages
- ☐ Describe the function and use of Instrument Society of America (ISA) block diagrams and instrument tags
- ☐ Identify the common symbols, line types, notations and indexes of a Process and Instrumentation Diagram (PandID)
- ☐ Use the common symbols, line types, notations and indexes of a PandID

- ☐ Power up a loop controller using a Honeywell UDC 3300
- ☐ Configure a loop controller using a Honeywell UDC 3300
- ☐ Calibrate a loop controller using a Honeywell UDC 3300
- ☐ Tune a loop controller using a Honeywell UDC 3300
- ☐ Operate a loop controller using a Honeywell UDC 3300
- ☐ Connect current to pressure (I/P) converters for final control elements
- ☐ Operate current to pressure (I/P) converters for final control elements
- ☐ Calibrate current to pressure (I/P) converters for final control elements
- ☐ Connect a diaphragm actuated proportional valve
- ☐ Operate a diaphragm actuated proportional valve
- ☐ Adjust a diaphragm actuated proportional valve
- ☐ Describe methods of measuring liquid level including a bubbler and a pressure sensor
- ☐ Convert between liquid level units, pressure units, sensor output units and display units
- ☐ Demonstrate the ability to connect, operate, test and display level using a capacitance pressure sensor
- ☐ Describe the function, operation, and application of ultrasonic level measurement
- ☐ Demonstrate the ability to connect ultrasonic level sensors and apply in a closed loop system for level control
- ☐ Demonstrate the ability to configure ultrasonic level sensors and apply in a closed loop system for level control
- ☐ Demonstrate the ability to operate ultrasonic level sensors and apply in a closed loop system for level control
- ☐ Describe the principles and operation of an on/off process control algorithm with alarms
- ☐ Connect electronic controllers to implement tank level control and alarm using an on/off algorithm and discrete inputs and outputs
- ☐ Configure electronic controllers to implement tank level control and alarm using an on/off algorithm and discrete inputs/outputs
- ☐ Operate electronic controllers to implement tank level control and alarm using an on/off algorithm and discrete inputs/outputs

- ☐ Use an electronic controller to control a process in proportional mode, proportional/integral mode, proportional / derivative mode and proportional/integral/derivative mode
- ☐ Describe methods of measuring flow including turbine sensors and paddlewheel sensors
- ☐ Convert between velocity, volumetric and mass flow rate units
- ☐ Describe how differential pressure is used to measure flow, the types of sensors used, types of orifice plates and the operation and function of a differential pressure (DP) transmitter
- ☐ Describe the operation of flow nozzles, venture tubes, and pitot tubes
- ☐ Measure flow using orifice plates, venture tubes and pitot tubes together with a differential pressure flow transmitter
- ☐ Demonstrate the ability to construct and operate a flow control loop using DP
- ☐ Demonstrate the ability to configure and implement a flow control loop using a paddlewheel sensor, a digital flow transmitter, a valve and a controller
- ☐ Describe loop optimization
- ☐ Calculate resolution and accuracy for a loop
- ☐ Tune a loop using the process reaction curve open-loop method, the Ziegler-Nichols closed-loop method and an automatic method
- ☐ Perform thermal energy calculations and conversions between temperature scales, energy units (BTU's Joules) and power units
- ☐ Calculate the energy needed to raise the temperature of a substance and the heat transfer rate to raise the temperature of a flowing fluid
- ☐ Describe the function, operation and application of heating elements, heat exchangers, chillers, thermostats and manual temperature controllers
- ☐ Describe the functions, operation, issues and applications of thermocouples, two (2) and three (3) wire RTDs and two (2), three (3) and four (4) wire
- ☐ Measure the outputs of thermocouples, RTDs and thermistors
- ☐ Demonstrate the ability to configure and implement a flow control loop using a paddlewheel sensor, a digital flow transmitter, a valve and a controller
- ☐ Describe the function and operation of temperature transmitters
- ☐ Configure transmitters for thermocouples, RTD's and thermistors
- ☐ Connect transmitters for thermocouples, RTD's and thermistors

FLUID POWER LEVEL II COMPETENCIES (CONTINUED)

- ☐ Demonstrate the ability to configure, connect and operate a controller for manual, on/off, time-proportional and proportional output control
- ☐ Describe a Distributed Control Systems (DCS) and its role in process control
- ☐ Compare a DCS to a PLC and stand-alone instrumentation

MECHANICAL COMPONENTS LEVEL I CERTIFICATE

This certificate covers the principles and applications of the most commonly found mechanical drive components as used in packaging machinery and systems. Topics include simple mechanical power transmission devices such as shafts, belts, chains, cams and gears with an emphasis on application and troubleshooting.

An understanding of simple mechanical components provides the background necessary to explore more complex systems of components used on all types of packaging equipment.

This certificate is aimed at entry level technicians who may be involved in the assembly, test, startup, troubleshooting, maintenance, repair or upgrade of basic packaging machinery modules.

MECHANICAL COMPONENTS LEVEL I COMPETENCIES

Introduction to Mechanical Drives and Safety

- ☐ Describe the function of a mechanical power transmission and give an advantage
- ☐ Describe five methods of rotary mechanical power transmission and give an application of each
- ☐ Describe five (5) rules of safe dress for working with power transmission equipment
- ☐ Describe the operation of the lockout/tagout system
- ☐ Describe the function of a foundation and give three types
- ☐ Describe three (3) types of motor mounts and give an application of each
- ☐ Describe how to select fastener size and type for a motor mount
- ☐ Describe how to mount and level an electric motor
- ☐ Select a fastener size and type for a motor mount
- ☐ Describe how fasteners are used to attach a motor mount to a bedplate
- ☐ Describe two (2) methods of measuring motor shaft speed and give an application

Key Fasteners

- ☐ Describe the construction of six (6) types of keys and give an application of each
- ☐ Describe how keys and key seats are specified
- ☐ Describe how to measure the actual size of a key and key seat
- ☐ Describe how to assemble a shaft to a hub using a key

- ☐ Describe two (2) methods of loading a mechanical drive system

Power Transmission and Shafts

- ☐ Convert between English and International System (SI) units of motor power
- ☐ Measure electric motor current
- ☐ Describe the function of a shaft and give an application
- ☐ List four (4) types of shaft materials and give an application of each
- ☐ Describe how shafts are specified
- ☐ Describe the function of a bearing and give an application
- ☐ Define three (3) types of bearing loads and give an example of each
- ☐ Describe how bearings are positioned to support a load
- ☐ Describe the operation of a two (2) categories of bearings and give an application of each
- ☐ Describe two (2) methods of mounting a shaft bearing and give an application of each
- ☐ Describe the function of a coupling and give an application
- ☐ Describe the function of four (4) categories of mechanical couplings
- ☐ Describe the operation of flexible jaw coupling
- ☐ Describe the purpose of shaft alignment and give two (2) types of misalignment
- ☐ Describe a general procedure for shaft alignment and give four (4) measurement methods
- ☐ Describe the operation of the straight edge and feeler gage method
- ☐ Identify shaft size given a sample

Lubrication

- ☐ List the six (6) functions of a lubricant
- ☐ Describe four (4) types of lubricant and give an application of each
- ☐ Describe the operation of five (5) types of lubrication application methods and give an example
- ☐ Describe three (3) types of oils and give an application of each
- ☐ Define viscosity and give its units of measure
- ☐ Describe how to use a viscosimeter and give an application
- ☐ Describe four (4) types of greases and give an application of each
- ☐ Describe five (5) lubricant storage rules
- ☐ Describe purpose and interpret a material data safety sheet (MSDS)

- ☐ Describe how to recycle and dispose of lubricants
- ☐ Select an oil specification for a given application
- ☐ Select a grease specification for a given application

V Belt Drives

- ☐ Define pitch, pitch circle, pitch diameter, and pitch length and explain their importance
- ☐ Describe how to calculate the pulley ratio and explain its importance
- ☐ Calculate pulley ratio
- ☐ Describe how to calculate the shaft speed and torque of a belt drive system
- ☐ Describe the operation of a fractional high powered V-belt drive
- ☐ Describe how to install and align a V-belt drive
- ☐ Describe three (3) methods of adjusting belt tension
- ☐ Describe three (3) methods of measuring belt tension and give an application of each
- ☐ Calculate the shaft speed and torque of a belt drive system
- ☐ Describe the function of a bushing and list three (3) types
- ☐ Describe the construction and operation of a Quick Detachable (QD) bushing and give an advantage
- ☐ Describe the construction and operation of a split taper bushing and give an advantage
- ☐ Describe the construction of a taper lock bushing and give an advantage
- ☐ Describe the construction and operation of a wedge V-belt drive
- ☐ Describe the construction and operation of a notched V-belt and give an advantage
- ☐ Describe the operation of a variable speed V-belt drive system and give an application
- ☐ Describe how to install and align a variable speed V-belt drive system
- ☐ Describe five (5) V-belt configurations and give an application of each
- ☐ Describe the function of a belt idler pulley and give an application
- ☐ Describe the operation of four (4) types of belt idler pulley configurations
- ☐ Describe how V-belts are specified
- ☐ Describe three (3) methods of identifying belt size and type
- ☐ Describe the function and operation of V-belt match codes
- ☐ Describe how sheaves and bushings are specified

- ☐ Describe how to select a V-belt, bushing and sheave for an application
- ☐ Describe preventive maintenance
- ☐ Describe nine (9) maintenance steps for V-belt drives
- ☐ Describe how to troubleshoot a V-belt drive system
- ☐ Troubleshoot a V-belt drive system

Chain Drives

- ☐ Describe the function of the three (3) basic components of a chain drive
- ☐ Describe how to calculate sprocket ratio and explain its importance
- ☐ Describe how to calculate the shaft speed and torque of a chain drive system
- ☐ List four (4) types of chain drives and give an application of each
- ☐ List four (4) types of roller chain drives and give an application of each
- ☐ Describe the operation of a single-strand roller chain drive
- ☐ Describe how to install, align and remove a roller chain drive system with adjustable centers
- ☐ Describe how to determine allowable chain sag for a given application
- ☐ Describe two (2) methods used to adjust chain sag
- ☐ Describe how to measure chain sag
- ☐ Describe the function and operation of a New Master Link
- ☐ Describe two (2) methods of installing a lightweight chain which uses a New Master Link
- ☐ Describe the operation of a chain puller
- ☐ Determine allowable chain sag for a given application
- ☐ Describe the operation of four (4) types of sprockets (No Hub, Single Hub, DoubleHub and Bushing) and give an application of each
- ☐ Describe the operation of a silent chain drive
- ☐ Describe how to install and align a silent chain drive system
- ☐ Describe the operation of a multiple strand chain drive
- ☐ Describe how to install and align a multiple strand chain drive system
- ☐ Describe the construction and operation of a taper lock busing and give an advantage
- ☐ Define chain pitch, pitch circle, pitch diameter, and pitch length of a chain drive and explain their importance
- ☐ Describe how chains are specified

- ☐ Describe how sprockets are specified
- ☐ Describe how to select the type and size of chain and sprocket for a given application
- ☐ Describe four (4) types of chain lubrication methods (manual, drip cup, oil bath or disc, and forced oil stream)
- ☐ Describe how to select a lubrication system for a chain drive system
- ☐ Describe how to select a lubrication type for a chain drive system
- ☐ Select a lubrication system for a chain drive system
- ☐ Describe ten (10) maintenance steps for chain drives
- ☐ Describe how to inspect and troubleshoot a chain drive system
- ☐ Troubleshoot a chain drive system
- ☐ Describe the operation of a chain breaker
- ☐ Identify the characteristics of a chain and sprocket given a specification
- ☐ Select a chain and sprocket for a given application

Gear Drives

- ☐ Define the pitch circle and pitch diameter and explain their importance
- ☐ Describe how to calculate the gear ratio of a gear drive
- ☐ Describe how to calculate the shaft speed and torque of a gear drive system
- ☐ List four (4) types of gear drives and give an application of each
- ☐ List four (4) types of parallel shaft gears and give an application of each
- ☐ Describe the operation of a spur gear drive
- ☐ Describe how to install and align a spur gear drive system with adjustable centers
- ☐ Describe the function of backlash
- ☐ Describe how to determine the allowable backlash in a gear drive
- ☐ Describe two (2) methods of measuring spur gear backlash
- ☐ Determine the allowable backlash in a gear drive
- ☐ Calculate gear ratio
- ☐ Calculate the shaft speed and torque of a gear train drive system
- ☐ Describe how to calculate the speed and torque output in a multiple shaft gear drive
- ☐ Describe the function of a compound gear drive system and give an application
- ☐ Describe how to install and align a multiple shaft drive system

- ☐ Describe the function of a solid coupling and list two (2) types
- ☐ Describe the operation of a sleeve coupling and give an application
- ☐ Describe how to align a coupling using an indicator
- ☐ Determine the direction of rotation of a gear given its position in a gear drive

Synchronous Belt Drives

- ☐ Describe the operation, selection, and the installation of a high torque drive (HTD) belt drive system
- ☐ Describe the operation, selection, and installation of a timing belt and pulleys for a given application
- ☐ Describe how to troubleshoot a synchronous belt drive system
- ☐ Troubleshoot a synchronous belt drive system

Couplings

- ☐ Describe the effect of thermal expansion on alignment and explain how to correct for it
- ☐ Describe the operation of chain, grid, and gear couplings
- ☐ Describe how to troubleshooting a coupling system

MECHANICAL COMPONENTS LEVEL II CERTIFICATE

This certificate builds and expands upon Mechanical Components Level I by covering the principles and applications of additional mechanical drive and fluid power components, expanding upon troubleshooting and looking at predictive and preventative maintenance techniques. Topics include mechanical power transmission devices such as gear drives and ball screws; laser alignment techniques; pneumatic logic, pressure and vacuum systems; vibration analysis; and central lubrication.

The following competencies, when combined with Mechanical Components Level I competencies, provides the advanced mechanical principles and skills that are required of a Mechatronics Technician in a complex high production manufacturing environment in discrete or hybrid industries such as electronics, automotive, food, pharmaceuticals, consumer products, packaging, metals, mining, or materials. When combined with Industrial Electrical Systems, the apprentice should be capable of troubleshooting and maintaining non-PLC based electro-pneumatic, electro-hydraulic, and moderately complex electro-mechanical equipment.

MECHANICAL COMPONENTS LEVEL II COMPETENCIES

- ☐ Apply basic safety rules for working with mechanical and pneumatic equipment, industrial lubricants, and conveyor systems
- ☐ Describe the function, construction and operation of synchronous timing and high torque drive belt systems
- ☐ Select components for, install, align, tension and troubleshoot synchronous belt systems
- ☐ Describe proper maintenance procedures for synchronous belt systems
- ☐ Measure the components of spur, bevel, helical, worm, and right angle gears
- ☐ Calculate speed and torque of gear systems
- ☐ Disassemble, install, adjust backlash and align shafts in systems using various gear train types
- ☐ Describe how gear systems are specified
- ☐ Apply lubrication and maintenance techniques for gear drive systems
- ☐ Describe the function and operation of plain, ball, roller, and antifriction bearings
- ☐ Explain how to specify, select, apply and lubricate these bearings
- ☐ Demonstrate the ability to remove, install, align, adjust, inspect, maintain and troubleshoot bearings using appropriate tools and methods

- ☐ Describe the function, construction and operation of linear ball bushings and ball screws
- ☐ Explain how to specify, select, and apply linear components
- ☐ Demonstrate the ability to install, adjust, inspect, maintain and troubleshoot linear ball bushings and ball screws
- ☐ Describe the function, construction and operation of gaskets, sealants, and seals
- ☐ Demonstrate the ability to elect, install, remove, inspect and troubleshoot gaskets and seals for various applications
- ☐ Describe the function, construction and operation of mechanical and electrical clutches, brakes, and clutch/brake combinations
- ☐ Perform calculations to specify clutches and brakes
- ☐ Demonstrate the ability to install and adjust clutches and brakes
- ☐ Demonstrate the ability to inspect, troubleshoot and maintain clutches and brakes
- ☐ Describe the purpose and function of lubricant types and additives
- ☐ Describe the methods of applying lubricants
- ☐ Demonstrate the proper use of manual lubricating equipment
- ☐ Describe the properties of a lubricant, measure the properties of a lubricant, and select the proper lubricant for an application
- ☐ Describe the purpose, function, components and operation of central lubrication systems
- ☐ Describe the operation, installation and maintenance of a series/progressive lubrication system
- ☐ Demonstrate the operation, installation and maintenance of a series/progressive lubrication system
- ☐ Describe the operation of a central lubrication controller
- ☐ Configure a central lubrication controller
- ☐ Demonstrate the ability to troubleshoot and repair a series/progressive system and controller
- ☐ Describe the operation and function of various types of shaft couplings using conventional methods
- ☐ Demonstrate the ability to install and precision align a variety of types of shaft couplings using conventional methods

- ☐ Describe the operation and function of laser shaft alignment
- ☐ Determine alignment tolerances, use a laser system to align, and store, recall and print alignment data on a power transmission system
- ☐ Describe the operation and function of conveyor systems
- ☐ Calculate conveyor lengths and speeds
- ☐ Demonstrate the ability to install, adjust and maintain flat belt conveyors
- ☐ Define preventive maintenance, predictive maintenance and total predictive maintenance
- ☐ Explain how vibration analysis may be used to implement various maintenance techniques
- ☐ Apply preventive maintenance, predictive maintenance and total predictive maintenance
- ☐ Explain how vibration analysis may be used to implement various maintenance techniques
- ☐ Describe the physics of vibration
- ☐ Demonstrate the ability to apply vibration sensors and interpret results of vibration measurements
- ☐ Describe causes of vibration in different types of components
- ☐ Demonstrate the ability to correct, isolate or dampen vibration
- ☐ Describe the function, application and operation of pneumatic directional control valves
- ☐ Design, install and operate circuits using manual, cam and pilot operated directional control valves
- ☐ Describe troubleshooting techniques for directional control and flow control valves
- ☐ Apply troubleshooting techniques for directional control and flow control valves
- ☐ Describe the function, application and operation of pneumatic power cylinders, pneumatic motors and air bearings
- ☐ Calculate torque, speed and air consumption for various loads, cylinders and motors
- ☐ Measure torque, speed and air consumption for various loads, cylinders and motors
- ☐ Demonstrate the ability to install and operate cylinders and motors

- ☐ Describe troubleshooting techniques for pneumatic cylinders, motors and rotary actuators
- ☐ Apply troubleshooting techniques for pneumatic cylinders, motors and rotary actuators
- ☐ Describe the function, application and operation of pneumatic logic
- ☐ Demonstrate the ability to design and simulate pneumatic logic circuits
- ☐ Demonstrate the ability to design, build and operate pneumatic circuits
- ☐ Describe the function, application and operation of single and two (2) stage air compressors and air compressor controls
- ☐ Apply the ideal gas law to air compressor operation and sizing
- ☐ Demonstrate the ability to operate and test air compressors
- ☐ Use instruments to measure operating conditions
- ☐ Describe troubleshooting techniques for conditioning equipment of an air system
- ☐ Apply troubleshooting techniques for conditioning equipment of an air system
- ☐ Describe the function, application and operation of vacuum systems including vacuum producing equipment; measuring units and equipment; vacuum switches; and vacuum cups and lifters
- ☐ Use Bernoulli’s Law to explain a venture
- ☐ Use Bernoulli’s Law to calculate vacuum lifting forces
- ☐ Demonstrate the ability to connect and operate a vacuum system for handling material
- ☐ Describe troubleshooting techniques for vacuum equipment and systems
- ☐ Apply troubleshooting techniques for vacuum equipment and systems
- ☐ Describe component and system level troubleshooting techniques, use a troubleshooting flowchart and troubleshoot electro-pneumatic systems using PLC indicator lights
- ☐ Apply component and system level troubleshooting techniques, use a troubleshooting flowchart and troubleshoot electro-pneumatic systems using PLC indicator lights

MOTORS AND MOTOR CONTROLS CERTIFICATE

This certificate covers the principles, application, troubleshooting and maintenance of rotating electrical motors and electronic motor drives as used in industry. Topics include various types of single and three phase AC motors, various types of DC motors, reduced voltage starting, braking, DC electronic drives, and AC variable frequency and vector drives. The certificate builds upon principles and applications covered in Industrial Electricity Level I and Level II and is a building block for the Robotics and Motion Control Certificate.

Mechatronics Technicians will work with motors and variable speed drive applications in a variety of machines and processes such as CNC machining centers, packaging machines, fans, and pumping systems. This Certificates verifies the skills and knowledge necessary to troubleshoot rotating electrical devices in an industrial environment such as electronics, automotive, food, pharmaceuticals, consumer goods, packaging, metals, mining and materials, pulp and paper, chemicals, water and wastewater, refining and energy.

MOTORS AND MOTOR CONTROLS COMPETENCIES

- ☐ Describe basic safety rules for working with electrical rotating machinery under 600 volts
- ☐ Apply basic safety rules for working with electrical rotating machinery under 600 volts
- ☐ Describe the operation, function, wiring and schematic symbols for DC series, DC shunt and DC Compound motors
- ☐ Connect, operate and reverse these motors
- ☐ Calculate both electrical and mechanical motor speeds, torques, and load
- ☐ Measure motor speeds, torques, and loads making both electrical and mechanical measurements
- ☐ Calculate motor power and efficiency for DC motors
- ☐ Plot torque, speed, power and efficiency for DC motors
- ☐ Analyze torque, speed, power and efficiency for DC motors
- ☐ Describe the performance characteristics for different motor types
- ☐ Describe AC waveforms, frequency, apparent power, power factor, effective voltage, peak voltage, single phase and three (3) phase power
- ☐ Measure AC waveforms, frequency, apparent power, power factor, effective voltage, peak voltage, single phase and three (3) phase power

- ☐ Demonstrate the ability to connect, operate, reverse, measure and graph the performance characteristics of single phase split phase, capacitor start, capacitor run, and capacitor start-run motors; and of three phase single voltage, dual voltage, wye and delta squirrel cage motors
- ☐ Describe the operation and function of motor braking by plugging, electromechanical braking, DC injection braking and dynamic braking
- ☐ Demonstrate the ability to connect, operate and troubleshoot the various braking methods
- ☐ Describe the operation and function of resistor, autotransformer and part winding motor starting
- ☐ Demonstrate the ability to connect, operate and troubleshoot the various reduced voltage/current starters
- ☐ Describe the operation and function of multi-phase AC power generators and transformers in combinations of wye and delta configurations for power distribution
- ☐ Demonstrate the ability to connect, operate and make measurements on various combinations of three (3) phase transformer configurations
- ☐ Describe the function and operation of Silicon Controlled Rectifiers (SCR) and how they may be applied for motor speed control
- ☐ Demonstrate the ability to connect, operate and measure performance characteristics of motors operating with full and half wave SCR control using an oscilloscope
- ☐ Describe the function, operation and construction of DC spindle drives, axis drives and pulse width modulation drives; the role of current, voltage, and velocity feedback from a tachometer in DC drives; and the set up and calibration of DC drives
- ☐ Demonstrate the ability to connect, calibrate and operate each type of drive monitoring the internal and external feedback signals and output with an oscilloscope
- ☐ Describe how DC motors operate and may be controlled using armature and field control
- ☐ Demonstrate the ability to operate DC motors using armature and field control
- ☐ Demonstrate the ability to select proper test equipment and troubleshoot the various types of DC motors and drives
- ☐ Describe the operation and function of variable frequency AC drives

- ☐ Demonstrate the ability to configure and operate variable frequency AC drives to control starting, stopping, speed, torque, acceleration, deceleration, boost, and braking
- ☐ Troubleshoot drive faults and parameters and systems incorporating variable frequency AC drives
- ☐ Describe the function, operation and construction of AC vector drives, AC induction motors and inverter-duty motors
- ☐ Describe how vector control is accomplished and the role of current and encoder feedback in an AC vector drive
- ☐ Demonstrate the ability to connect, configure, operate and measure parameter of with an oscilloscope
- ☐ Troubleshoot vector drives
- ☐ Describe the function, operation and construction of AC axis drives and 3 (3) phase DC brushless motors
- ☐ Demonstrate the ability to connect, calibrate, operate, trace and measure signals with an oscilloscope
- ☐ Troubleshoot AC axis drives

ROBOTICS AND MOTION CONTROL CERTIFICATE

PREREQUISITES: MOTORS AND MOTOR CONTROLS
PROGRAMMABLE LOGIC CONTROLLERS (PLC'S) LEVEL I

This Certificate provides apprentices with a background in the programming and application of industrial robots and general purpose synchronized multi-axis motion control. Whereas in Motors and Motor Controls apprentices learned how various types of motors and drives operate to create motion in a single axis, this Certificate expands upon those concepts by combining multiple axes of motion to perform useful functions such as creating a flexible manufacturing system utilizing robots. In Programmable Logic Controllers Level I, the apprentice learned how to apply programming to create sequences of events. This Certificate broadens that knowledge by using different programming languages to initiate and control motion sequences. The apprentice will learn how to implement electronically many of the simple machines introduced in Mechanical Components Level I and Level II, such as gear drives, belt drives, line shafts and cams. This Certificates also introduces the apprentice to techniques and products that are based upon International Electrotechnical Commission (IEC international standards and discusses the concepts of standards-based control.

Industrial robots are used in a wide range of industries such as machine tool, automotive, food processing and packaging. General purpose motion control is used not only to build robots but also in specific stand-alone applications in printing, converting, packaging, and processing. This Certificate verifies an apprentice's ability to assist in the application, operation and maintenance of these technologies in discrete and hybrid industries.

ROBOTICS AND MOTION CONTROL COMPETENCIES

- ☐ Describe safety rules and devices for working with or around industrial robots
- ☐ Describe advantages, functions, components, operation and applications of industrial robots and end effectors
- ☐ Describe how robots are applied to material handling, plastic injection molding, CNC machine loading, and parts inspection
- ☐ Describe how robots are applied to packaging of food and consumer products by collating, picking, placing, orienting, cartooning, casing and palletizing
- ☐ Describe the function, operation, storage and retrieval of robot programs and position points
- ☐ Describe the use, function and operation of on-line programming, off-line programming, teach pendants, operator stations, and digital inputs and outputs for industrial robots

- ☐ Use a teach pendant to teach robot position points, test points and edit points
- ☐ Use a teach pendant to enter, test, edit, run, stop, store, delete, and retrieve robot programs and to power up, shut down, jog, home and operate the arm and gripper of an industrial robot
- ☐ Use a teach pendant to test digital inputs/outputs
- ☐ Use a PC and robot programming software to design, enter, edit, upload, download, delete and run robot programs and to power up, power down, jog and home a robot
- ☐ Use the following commands in a robot program: PMOVE, LABEL, BRANCH, GRASP, RELEASE, SPEED, DELAY, WAITI, WRITEO, MON, MOFF, IF-THEN, IFIN, ELSE, ENDIF, INP, CALL, RETURN, SUB, DDMOVE, TESTI, FLAG, SET, RESET, IF FLAG, FOR, NEXT, STEP, MEASURE, PRINT, PRINTLN, IFCT, INCR CTR, DECR CTR, CLEAR CTR, GRWIDTH, DPMOVE, POINT, LMOVE, LINEAR, XMOVE, YMOVE, ZMOVE, XTLMOVE, YTLMOVE, ZTLMOVE, PALLET, GETPART, NEXTPART, REPEAT, UNTIL, SETPART, PREVPART, PALLETPT, TESTP, CHR$, ASC, RIGHT$, LEFT$, MID$, RUN, HALT, MONITOR, ENDMONITOR, SENSOR, GUARD, ENDGUARD, and QPOSITION
- ☐ Use flow charts to design programs with conditional, branching, subroutine, multitasking and interrupt functions
- ☐ Use variable names, variables, global variables, point variables and point arrays in a robot program
- ☐ Use the Cartesian Coordinate System to command robot position and program with World Coordinates and Tool Coordinates
- ☐ Demonstrate how to connect, configure, program and operate a robot in conjunction with both servo-driven and non-servo-driven conveyors
- ☐ Design robot programs to handle material, use operator stations, unload an automatic machine, interface with conveyors, sort parts, measure parts, provide an operator interface on a computer screen, perform palletizing, perform point-to-point assembly, perform linear motion assembly, and exchange data with a barcode reader or gauge
- ☐ Describe how to interface a robot to other machines such as a CNC or packaging machine using solid state I/O, relays or RS-232 serial communications
- ☐ Use robot simulation software to design a workcell
- ☐ Describe the functions, components and operations of general purpose, synchronized, multi-axis motion control
- ☐ Describe the use of real and virtual master axes

- ☐ Demonstrate the operation of electronic camming, gearing, lineshafting and clutching
- ☐ Describe the need for deterministic networking for the implementation of synchronized multi-axis motion control
- ☐ Describe the applicable standards and commonly used networks for motion control
- ☐ Describe the three controller types and the four network types that may be involved in a multi-axis motion control application
- ☐ Describe the programming languages that are specified by IEC 61131 and the advantages and disadvantages of each for various types of applications.
- ☐ Use an IEC61131 programming language to design and implement a synchronized multi-access motion control application
- ☐ Describe the PLC Open motion function blocks
- ☐ Describe the purpose of International Standards and the advantages and disadvantages of applying standards-based control
- ☐ Use PLC Open motion function blocks to implement a synchronized multi-axis motion application
- ☐ Describe how multi-axis motion control is applied to construct a robot arm
- ☐ Describe how multi-axis motion control is applied to applications such as printing, depositing, molding, wrapping, and bagging
- ☐ Describe the issues of interfacing a high speed synchronized motion application with a PLC
- ☐ Troubleshoot a multi-axis motion system